NPS Form 10-900
(Rev. 10-90)

OMB No. 1024-0018

United States Department of the Interior
National Park Service

NATIONAL REGISTER OF HISTORIC PLACES
REGISTRATION FORM

This form is for use in nominating or requesting determinations for individual properties and districts. See instructions in How to Complete the National Register of Historic Places Registration Form (National Register Bulletin 16A). Complete each item by marking "x" in the appropriate box or by entering the information requested. If any item does not apply to the property being documented, enter "N/A" for "not applicable." For functions, architectural classification, materials, and areas of significance, enter only categories and subcategories from the instructions. Place additional entries and narrative items on continuation sheets (NPS Form 10-900a). Use a typewriter, word processor, or computer, to complete all items.

1. Name of Property

historic name Langley Field and Langley Memorial Aeronautical Laboratory

other names/site number Langley Air Force Base and NASA Langley Research Center

2. Location

street & number _____

not for publication ___

city or town Hampton

vicinity ___

state Virginia *code* VA *county* Hampton(Indep.City) *code* 650

zip code 23665

3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act of 1986, as amended, I hereby certify that this ____ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ____ meets ____ does not meet the National Register Criteria. I recommend that this property be considered significant ___ nationally ___ statewide ___ locally. (___ See continuation sheet for additional comments.)

_____ _____
Signature of certifying official *Date*

_____
State or Federal agency and bureau

Thomas W.L. McCall, Jr.
Deputy Assistant Secretary of the Air Force
(Environmental, Safety and Occupational Health)
Federal Preservation Officer

In my opinion, the property ____ meets ____ does not meet the National Register criteria. (___ See continuation sheet for additional comments.)

_____ _____
Signature of commenting or other official *Date*

_____
State or Federal agency and bureau

Kenneth Kumor
Facilities Operations and Maintenance Division
National Aeronautics and Space Administration
Federal Preservation Officer

In my opinion, the property ____ meets ____ does not meet the National Register criteria. (____ See continuation sheet for additional comments.)

_____ _____
Signature of commenting or other official *Date*

H. Alexander Wise, Jr.
State Historic Preservation Officer
Virginia Department of Historic Resources

4. National Park Service Certification

I, hereby certify that this property is:

____ entered in the National Register _____ _____
___ See continuation sheet.
____ determined eligible for the _____ _____
National Register
___ See continuation sheet.
____ determined not eligible for the _____ _____
National Register
____ removed from the National Register _____ _____

____ other (explain): _____

_____ _____
Signature of Keeper *Date of Action*

5. Classification

Ownership of Property
(Check as many boxes as apply)

___ private
___ public-local
___ public-State
_X_ public-Federal

Category of Property
(Check only one box)

___ building(s)
_X_ district
___ site
___ structure
___ object

Number of Resources within Property
(Do not include previously listed properties in the count)

Contributing	Noncontributing	
247	43	buildings
	2	sites
38	48	structures
	1	objects
285	94	Total

Number of contributing resources previously listed in the National Register 2

Name of related multiple property listing (Enter "N/A" if property is not part of a multiple property listing.) N/A

6. Function or Use

Historic Functions (Enter categories from instructions)	*Current Functions* (Enter categories from instructions)
Defense: air facility	Defense: air facility
Domestic: institutional housing	Domestic: institututional housing
Other: Science/Engineering: aeronautical laboratory	Other: Science/Engineering:aeronautical laboratory

7. Description

Architectural Classification (Enter categories from instructions)	*Materials* (Enter categories from instructions)
Late 19th and Early 20th Century Revivals: Colonial Revival, Classical Revival, Tudor Revival, Spanish Colonial Revival, Italian Renaissance. Other: WWII Temporary	*foundation*: brick, stone *walls*: brick, stucco, weatherboard *roof*: slate, tile, asphalt *other*: walls: asbestos, hollow tile steel wind tunnel structures

Narrative Description (Describe the historic and current condition of the property on one or more continuation sheets.)

8. Statement of Significance

Applicable National Register Criteria (Mark "x" in one or more boxes for the criteria qualifying the property for National Register listing)

_X_ A Property is associated with events that have made a significant contribution to the broad patterns of our history.

_X_ B Property is associated with the lives of persons significant in our past.

_X_ C Property embodies the distinctive characteristics of a type, period, or method of construction or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components lack individual distinction.

___ D Property has yielded, or is likely to yield information important in prehistory or history.

Criteria Considerations (Mark "X" in all the boxes that apply.)

___ A owned by a religious institution or used for religious purposes.

___ B removed from its original location.

___ C a birthplace or a grave.

___ D a cemetery.

___ E a reconstructed building, object,or structure.

___ F a commemorative property.

_X_ G less than 50 years of age or achieved significance within the past 50 years.

Areas of Significance
(Enter categories from instructions)

Military
Science
Engineering
Architecture
Education
Invention
Commerce
Industry
Transportation
Communications
Social History
Community Planning and Development
Landscape Architecture

Period of Significance

1917-1947 Army air arm
1917-1958 NACA

Significant Dates

1920
1921
1935

Significant Person
(Complete if Criterion B is marked above)

Albert Kahn
Brig. Gen. William Mitchell
Max Munk
Eastman Jacobs

Cultural Affiliation

Euro-American

Architect/Builder

Albert Kahn
Army Quartermaster Corps

Narrative Statement of Significance (Explain the significance of the property on one or more continuation sheets.)

9. Major Bibliographical References

(Cite the books, articles, and other sources used in preparing this form on one or more continuation sheets.)

Previous documentation on file (NPS)
___ preliminary determination of individual listing (36 CFR 67) has been requested.
___ previously listed in the National Register
previously determined eligible by the National Register
_X_ designated a National Historic Landmark
___ recorded by Historic American Buildings Survey # _____
___ recorded by Historic American Engineering Record # _____

Primary Location of Additional Data
___ State Historic Preservation Office
___ Other State agency
_X_ Federal agency
___ Local government
___ University
___ Other

Name of repository: Langley Air Force Base-Civil Engineering Squadron
NASA Langley Research Center

10. Geographical Data

Acreage of Property _____

UTM References (Place additional UTM references on a continuation sheet)

	Zone	Easting	Northing		Zone	Easting	Northing
A	__	_____	_____	D	__	_____	_____
B	__	_____	_____	F	__	_____	_____
C	__	_____	_____	F	__	_____	_____

___ See continuation sheet.

Verbal Boundary Description (Describe the boundaries of the property on a continuation sheet.)

Boundary Justification (Explain why the boundaries were selected on a continuation sheet.)

11. Form Prepared By

name/title Jody Cook, Architectural Historian

organization National Park Service, Southeast Field Area

date June 15, 1995

street & number 75 Spring Street, S.W. *telephone* (404) 331-2641

city or town Atlanta *state* GA *zip code* 30303

Additional Documentation

Submit the following items with the completed form:

Continuation Sheets

Maps

A USGS map (7.5 or 15 minute series) indicating the property's location.
A sketch map for historic districts and properties having large acreage or numerous resources.

Photographs

Representative black and white photographs of the property.

Additional items (Check with the SHPO or FPO for any additional items)

Property Owner *(Complete this item at the request of the SHPO or FPO.)*

name United States Air Force

street & number _____ *telephone* _____

city or town _____ *state* ____ *zip code* _____

Description of Historic Resources

The Langley Field Historic District is the easternmost section of Langley Air Force Base. The base is near the center of the southern end of the lower Virginia Peninsula in Hampton, Virginia, about six miles northwest of the Chesapeake Bay. The land is flat and large sections were originally marshland that has been backfilled. The historic part of the base is surrounded on its north, east, and south sides by the northwest and southwest branches of the Back River, a Chesapeake Bay estuary. The Langley Field Historic District includes three distinct historic areas: the **Heavier-than-Air (HTA) Area** in the southern part of the district (which includes the **NASA Langley Research Center-East Area**), the **Lighter-than-Air (LTA) Area** in the northern part of the district, and the airfield that separates the two. The historic district includes 379 resources constructed between 1917 and 1958, and 76 percent of the resources contribute to the district's character. These historic resources are associated with the development of Langley Field and its two Federal occupants, the air arm of the United States Army, and the National Advisory Committee for Aeronautics (NACA), the parent agency of the National Aeronautics and Space Administration (NASA).

The NASA Langley Research Center-East Area (NASA East Area) is in the southeastern part of the Langley Field Historic District. This was the location of NACA's first laboratory, the Langley Memorial Aeronautical Laboratory (LMAL). The character of the NASA East Area, along the waterfront at the district's southeastern boundary, is generally industrial. All of the resources (28) associated with the laboratory are in this area, and most of these facilities are wind tunnels. Langley's wind tunnel complex includes three National Historic Landmarks, designated in 1985 following the National Park Service's **Man in Space** theme study. The period of significance for NACA/LMAL resources is 1917-1958. Additional research may eventually require an extension of the closing date for the period of significance to more accurately reflect the time period when LMAL made the contributions on which its significance is based. NACA/LMAL resources are described in detail beginning on page 6.

Most of the historic district's resources are associated with Langley Field's role in the development of the air arm of the U.S. Army. The period of significance for these resources is 1917-1947. The air arm resources illustrate a number of property types characteristic of early Army flying fields: administration, operations (hangars, maintenance and repair shops, infrastructure), residential, recreation, and social types of buildings. These buildings are generally constructed of brick, and are low in scale (1-3 stories). A variety of architectural styles are seen in the historic district, all of which are revival styles of the early 20th century: Tudor Revival, Italian Renaissance Revival, Colonial Revival, Classical Revival, and Spanish Colonial Revival. The district has a cohesive quality provided by its historic road systems in the HTA and LTA Areas, compatible architectural styles, similar building materials, low-scale building types, and historic landscape features.

The Langley Field Historic District has a very high degree of integrity because its low percentage of non-historic resources and minimal number of incompatible alterations to historic building exteriors do not seriously detract from its cohesive elements.

In the 1910s, 1920s, and 1930s, Langley Field was land-locked; a bridge over the southwest branch of the Back River historically provided access from King Street in Hampton. The King Street bridge connects with the traffic circle at the southwestern boundary of the historic district, in the HTA Area. The King Street bridge still provides access to Langley, but the base's main entrance is now located further west at LaSalle Avenue. LaSalle connects with Nealy Avenue, the primary road through Langley's western section, where most non-historic development has occurred. The intersection of Nealy and Hammond Avenue (one of Langley Field's two historic boulevards) is marked by the base's only traffic light, clearly distinguishing the historic western boundary of Langley Field.

THE HEAVIER-THAN-AIR (HTA) AREA

Langley's historic development is concentrated in the HTA Area. The 1917 pie-shaped road system is a major feature of the HTA Area, with its traffic circle at the point, two radiating boulevards with smaller traffic circles at their ends, and arc-shaped interconnecting streets. Beyond the "pie" system of roads is a grid plan of blocks in the southern section of the district. The HTA Area also includes residential areas for officers, the flight line with its double row of hangars, and all the technical, maintenance, supply facilities, and infrastructure necessary to support Langley's historic operations. The operations facilities are located adjacent to the flightline (generally in the middle of the district), and along the waterfront at the district's southeastern edge. The residential area, with officers' housing, historic barracks, administration, recreation, and social buildings, is located between the two historic operations areas.

The HTA Area has Langley's most architecturally significant buildings, constructed between 1917 and the early 1930s. There were really two distinct periods of development associated with the Army's air arm at Langley Field during this time, 1917-1924 and 1930-1935. In the 1917-1924 period, most of the buildings, as well as the road layout, were designed by noted industrial architect Albert Kahn and Associates of Detroit, Michigan. This group includes 26 residential duplexes illustrating 13 different house types, all variations of an English cottage (Tudor Revival) style. Two of Kahn's most prominent buildings for Langley were the Army Aeronautical Laboratory (No. 693, now Headquarters Air Combat Command) and Lawson Hall (No. 472) in the Italian Renaissance Revival style. Both buildings have expansive, low-pitched hipped roofs, wide, overhanging eaves, symmetrical facades with projecting wings or pavilions, and accented entrances. Administration and operations buildings designed by Kahn feature elaborate brickwork, with military-related symbols and decorative panels in their gable ends, friezes, and at entrances. Expansive

curtain walls with steel-framed windows and movable doors were also characteristic features of original operations buildings designed by Kahn.

In the early 1930s, another major construction program was carried out at Langley Field by the Army Quartermaster Corps. The Quartermaster Corps (QMC) designed some of these buildings in accordance with the architectural direction established by Kahn in the late 1910s. The large historic barracks buildings employ the Italian Renaissance Revival features of the larger buildings constructed in the first building period: expansive low-pitched roofs with wide, overhanging eaves, symmetrical facades with accented entrances, and decorative panels with patterned brickwork. The officers' residences along Benedict Avenue show many high-style features of the Tudor Revival style, continuing and expanding the English cottage style established with Langley's first residential construction. In addition, some buildings were constructed during the early 1930s in accordance with architectural design guidelines established by the Quartermaster Corps in the late 1920s. The Colonial Revival style was chosen for Army construction along the Eastern seaboard to reflect the historic building traditions of this part of the country.

THE HTA AREA:
Development in the 1917-1924 Period

Major construction work began in 1917 and ceased temporarily with the Armistice ending the First World War in November 1918. Sixteen of 26 residential duplexes planned were completed by that time, and the remaining residences were completed by June 1920. Other permanent buildings completed after the Armistice included: The Army Aeronautical Laboratory (1919, No. 693), Dodd Hall (1919, bachelor NCO quarters, No. 448), Lawson Hall (1919, bachelor officer quarters, No. 472), a machine shop (1918, No. 661), and two ornate brick hangars (1919, No. 777 and 1918, No. 781).[1] A number of other operations type buildings were constructed adjacent to the docks along the waterfront at the district's southern boundary: a reclamation and oil house (1920, No. 596), a truck shed (1920, No. 606), Officers' Club (1921, later the boat house, No. 609, demolished), a technical stores building (1920, No. 623), a water tank (1921, No. 620) and a large seaplane hangar (1921, No. 633). The first permanent

[1]The building numbers shown refer to "facility numbers" commonly used at military installations and shown on the Langley Air Force Base map. Facility numbers are included in Langley Field's Inventory of Historic Resources (attached). Since the initial survey of historic resources at Langley and the preparation of this nomination, street addresses have been designated for all buildings. A conversion list is included with the nomination to address this issue.(Residential buildings had street addresses and facility numbers prior to designation of street addresses for all buildings, and addresses for residential buildings are shown in the inventory.)

barracks for enlisted men, Austin Hall (No. 546) was completed in 1924 in the HTA Area (later the location of the Air Corps Tactical School). Even though two-thirds of Langley's buildings were still temporary wartime construction at that time,[2] Langley was the Army's largest flying field in the United States, and the only Army air station with a number of substantial, permanent buildings.

THE HTA AREA:
Development in the 1930-1935 Period

Major development also occurred at Langley Field in the early 1930s. New buildings and infrastructure in the HTA Area included: the seawall (1931), a hospital (1931, No. 558), two adjacent duplexes for medical NCO housing (1931, No. 567, No. 570), parachute building (1931, No. 784), radio building (1931, No. 607), eleven hangars on the flight line (1932), the guardhouse (1932, No. 714), photo laboratory (1932, No. 788), a gymnasium (1933, No. 658), a theater (1933, No. 657), fire station (1933, No. 700), chapel (1935, No. 520), and a new bridge across the Back River (1935, No.404), replacing the original bridge damaged by a hurricane in 1933. A number of these buildings exhibit Colonial Revival features, in keeping with the architectural design guidelines established by the Quartermaster Corps.

A major program of residential construction (48 buildings) was also undertaken. Large areas of World War I temporary buildings were demolished and replaced with officers quarters—sizable single houses and large duplexes. In 1931, 19 large duplexes for field grade officers were completed in the HTA Area. They filled in blocks originally laid out by Albert Kahn, although they were not constructed in the locations Kahn had designated. All of these two-and-a-half story brick and stucco Tudor Revival style residences are identical, except that end sections of nine buildings are gabled and the remaining ten have hipped roofs end sections. In 1932, six individual houses (three house types) and three more of the large duplexes were completed. These buildings were sited at various open areas, tying the earlier English cottage type houses (1918-1920) and 1931 duplexes together as a cohesive "neighborhood." Six large barracks buildings were also constructed in 1932 (No. 635, No. 664, No. 669, No. 671, No. 681, No. 703). Four of these barracks were arranged around a quadrangle, with large, wraparound porches on all rear facades, facing a large open green space. Some of the porches have been enclosed, and the former green space has been paved for parking. These buildings are Italian Renaissance Revival in style, continuing the architectural design established in the earliest period of construction by Albert Kahn for Langley's most prominent buildings.

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[2]Jerold E. Brown, "Where Eagles Roost; A History of Army Airfields Before World War II," (Ph.D. diss., Duke University, 1977), 138, citing "Annual Report of the Chief of Air Service, 1925," 27.

The seawall construction in 1931 and associated backfill along the Back River allowed the addition of a new street, Benedict Avenue. It paralleled Dodd Boulevard and allowed the original street plan to be extended one block to the southeast. Twelve general officers' quarters were completed here in 1934, along what came to be known as "Gold Coast Row." These large brick houses are high-style examples of the Tudor Revival style. There are three different house types--nine identical "type As," one "type B" for the commanding general, and two "type Cs." Two more large duplexes and six residential garages were also finished in 1934 in the HTA Area. A "new" Officers Club (No. 412) was constructed in 1935 on the site of the Sherwood plantation house. In terms of construction, there has been little change in the appearance of the HTA Area since the mid 1930s.

Historic building exteriors in the HTA Area retain their integrity more so than interiors. Characteristic exterior architectural features that give added significance to buildings in the HTA Area include elaborate brickwork, slate roofs, copper-covered porch roofs with lattice-work columns, brackets, cast and carved limestone lintels, and heavy wooden garage doors with multi-light windows at the top. In general, additions to historic buildings are not compatible with a building's original design and character. They have been placed on rear or side facades, however, allowing the more visible street facades to retain their historic appearance. Incompatible replacement windows with metal frames and tinted glazing (some with fake muntins) are found in most buildings. Historic photographs document the wood double hung and metal casement windows originally installed in the residential and administration buildings. Some of the oldest officers' quarters (1918-1920) still retain their historic wood windows. Historic steel windows are still found in most of the hangars and some of the technical, maintenance, and storage buildings.

A sampling of HTA Area interior spaces indicates that their integrity is generally determined by building type. The officers' houses appear to retain original floor plans and historic materials, although porches on the earliest residences (1918-1920) have been enclosed. Operations buildings and former barracks (now serving administration functions) were apparently gutted, losing their original floor plans and historic fabric. The Chapel's original interior has not been altered, and the former elementary school generally retains its plan and historic materials. Interiors in other types of buildings (hangars, technical, etc.) cannot be generally characterized. Some hangars and former technical buildings are now used as storage areas. Their historic fabric has been removed, particularly steel windows, although some features may still exist behind applied covering materials. Other technical and maintenance buildings now function primarily as office space. Gutting or infill of large interior spaces was apparently undertaken to provide this adaptive use.

Additional construction in the HTA Area is described below under the headings World War II Temporary Buildings and Noncontributing Resources (p. 11).

HTA Area:
Historic Landscape Features
Much of Langley Field was marshland before construction began in 1917; some inlets were backfilled and a seawall was constructed to establish the more uniform shoreline that exists today. Any natural features that once existed, other than the generally flat character of the land, are no longer extant. The first conscious design effort on the site was the road circulation system laid out in 1917 by Langley Field's original architect, Albert Kahn. The pie-shaped street layout that defines the area's southwestern end retains its large central traffic circle, boulevards to the northeast (Dodd Boulevard) and northwest (Hammond Avenue), and arced, interconnecting interior streets. The smaller traffic circles, originally the terminations of the boulevards, have been compromised. The circle at the end of Hammond Avenue is now the base's main intersection, requiring a traffic light. The outline of the circle formerly at the end of Dodd Boulevard is still extant, but its interior island has been paved over and it no longer functions as a traffic circle. The original grid plan of the blocks beyond this intersection (to the northeast) is still intact. Curbs that were part of this original street layout have metal nosings.

Historic photographs indicate that there was no real attempt to landscape the HTA Area until the mid 1930s, when landscaping was initiated by Depression era Public Works Administration (PWA) projects. There were concrete walks from streets to front doors of residential, administration, and operations buildings, but a system of sidewalks did not begin to appear until this time. Grass strips between the back of the curb and these new sidewalks were planted with large deciduous shade trees (oak, sycamore). In the residential areas, smaller ornamental trees (dogwood, cherry, plum) and evergreens were planted in yards. Ornamental foundation plantings (juniper, holly) also appear to be part of the original landscape design, in residential as well as operations areas of the historic district. Trees, shrubs, and open areas established in the 1930s have matured, creating a park-like neighborhood setting. Most shrubs are now overgrown and pruned to uniform heights and shapes, contrary to the intent of the original landscape plan.

Other important elements in Langley Field's historic landscape are 1917 and 1918 manhole drain covers with raised letters and flags of the Army Signal Corps and the Division of Military Aeronautics, part of the drainage system necessary for this low-lying land. There are also numerous historic street lights located in the grass strips of the street right of way (1933, although some are now reproductions). These elements are not numbered facilities on the base map and were not included in the Inventory of Historic Resources, but they do contribute to the character of the historic district.

THE NASA EAST AREA
The NASA East Area is located in the HTA Area along the waterfront. It contains two separate sections; the land lot originally assigned to NACA for its

aeronautical laboratory, the Langley Memorial Aeronautical Laboratory, and additional acreage at the southeastern edge of Langley Air Force Base along the waterfront. These sections are now referred to as the NASA East Area, although some of the facilities, originally constructed by NACA, are currently used by Langley Air Force Base.

At LMAL's original location (Plot No. 16), there are 10 facilities associated with NACA, which were constructed between 1918 and 1940. Plot 16 is the site of NACA's first laboratory building (1918, No. 587) and the building constructed to house NACA's first wind tunnel (1920, No. 580). The Variable Density Tunnel (VDT, 1922), a National Historic Landmark (1985), was originally located in this section, but it was relocated to the NASA West Area in 1990. The VDT was initially housed in a temporary building at the current location of Facility No. 582, now a compressor station. Facility No. 582A was constructed for NACA's third generation VDT, the Low Turbulence Pressure Tunnel (LPTP, 1940, No. 582A). Other historic NACA facilities in this section include a service building (1926, No. 586), maintenance building (1929, No. 583A), utility building (1935, No. 584), and two more wind tunnels (1934, No. 585; 1938, No. 583). All of the historic buildings in this section that housed NACA facilities are constructed of brick, and they all contribute to the character of the Langley Field Historic District.

LMAL's oldest buildings exhibit classical features and attention to architectural details. The front entrance of the laboratory (1918, No. 587) has a pedimented entrance with Doric columns, a projecting cornice, and limestone door surrounds and watertable. The building that housed NACA's first wind tunnel (1920, No. 580) has the patterned brickwork at the frieze that is characteristic of Langley's early buildings designed by Albert Kahn. Brick buildings constructed for LMAL from the late 1920s to the early 1940s are more utilitarian in appearance, although the service building (1926, No. 585) and No. 582-582A (1940) are articulated with concrete window sills and bands at the cornice. Facility No. 582A is a two-story, multi-bay office building, only 21 feet deep, located immmediately in front of the steel wind tunnel structure, which is completely exposed. NACA's first high-speed vertical jet tunnel (No. 585) was enclosed in a tank in 1949, giving this section of plot 16 a somewhat industrial appearance.

Continuing along the waterfront to the east about a block and-a-half is another section of the NASA East Area, at the southeastern boundary of the historic district. This section has an industrial character. By the mid-1920s, LMAL had outgrown the original laboratory site; it was not nearly large enough to construct the vast wind tunnels LMAL research required by that time. The form of buildings constructed to house various wind tunnels and other research facilities was dictated by the shape of the research equipment and its structural requirements. "Langley's most striking physical feature was its unique collection of wind tunnels, many of which were of unprecedented design and capability. To a few observers, Langley's tunnels might have looked like

huge, ungainly, wormlike creatures, washed ashore perhaps after a battle of primordial monsters in the nearby tidal river. But the tunnels were no less fascinating to those whose gaze was less imaginative. Some tunnels might have looked only like big warehouses with jointed appendages and rounded corners, but they were all in fact complicated mechanized marvels, national resources, great and powerful monuments to the modern age."[3]

There are 18 facilities in this section associated with NACA, constructed between 1930 and 1953. The first wind tunnel in this area was the Propeller Research Tunnel (PRT, 1927, demolished 1950). The size of its throat (20 feet) was unprecedented, the largest of any tunnel in the world at that time. The group of 18 facilities includes ten historic research facilities (all contributing resources), three cooling towers (noncontributing), two substations (contributing), two research office buildings (one is a contributing resource), and a shop building (contributing).

The Full-Scale Tunnel (1931, No. 643-NHL, 1985) is LMAL's largest research facility, and it towers above the rest of the historic district. The 30x60 foot tunnel is housed in a large building with exposed steel framework supporting the building's walls of corrugated careystone. Its dimensions are 435 feet x 222 feet x 82 feet (average height), and it occupies 108,700 square feet of ground area, including the hangar addition. Tank No. 1 (1930, No. 720) is known as the mile-long building, but it is actually a seaplane towing tank, originally 2020 feet by 24 feet wide and 12 feet deep. A two-story brick office building (No. 720) was constructed in 1936 at the west end of Tank No.1 (also No. 720), and the tank was extended to 2,960 feet (from 2,020) that same year. The Free-Spinning Wind Tunnel (1934, No. 646) was housed in a rectangular steel structure with corrugated asbestos (careystone) walls. LMAL's first high-speed tunnel of large size was the 8-Foot High-Speed Tunnel (1936, No. 641-NHL, 1985). Its reinforced concrete tunnel was built with 12 inch thick walls, and its office and motor buildings were constructed of stuccoed hollow tile. A substantial addition to the office building was made in 19??. The facility currently serves as offices for the Transonic Pressure Tunnel (1953, No. 640).

The 19-Foot Pressure Tunnel (1938, No. 648) is now known as the Transonic Dynamics Tunnel. Its three-story, multi-bay brick office building, only 32 feet deep, is located immediately in front of the steel wind tunnel structure, which is completely exposed. The length of the office building was doubled with a 19?? addition. The Free-Flight Tunnel (1939, No. 644), is a 60-foot diameter sphere with 3/8 inch thick steel exterior. The East Shop/Technical Services Building (1939, No. 647) has a steel framed structure with brick walls and

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[3]James R. Hansen, **Engineer in Charge—A History of the Langley Aeronautical Laboratory, 1917-1958** (Washington, D.C.: National Aeronautics and Space Administration, The NASA History Series, 1986), 23.

steel framed windows. It housed an erection shop, machine and woodworking shops, and a drafting room. The 20-Foot Spinning Tunnel/Vertical Spin Tunnel, (1941, No. 645) is a 12-sided vertical polygon tunnel, approximately 63 feet in diameter at the base and 75 feet high, a steel structure covered with asbestos cement siding and roofing. A second tow tank (No. 720B) was constructed in 1942 alongside Tank No.1 (No. 720), and a Dynamic Model Shop/Seaplane Impact Basin (1943, No. 720A) was also constructed by the towing tanks. The 8-Foot Transonic Pressure Tunnel (1953, No. 640) was constructed on the site of the Propeller Research Tunnel. The wind tunnel structure is exposed, and office space was provided by renovating the 8-Foot High Speed Tunnel (No. 641). All of these research facilities are contributing elements to the historic district. In addition, there are two electrical substations constructed during the NACA/LMAL period of significance (1917-1958). Mathis Road Substation (1938, No. 650) and Back River Substation (1941, No. 642) were critical elements in providing the enormous amounts of electrical power necessary to operate the wind tunnels. Both are considered contributing structures. The rest of the facilities in this area are noncontributing resources, all built in the 1980s (three cooling towers and one office building).

THE LIGHTER-THAN-AIR AREA

Historic development at Langley Field also occurred in the **LTA Area**, directly north of the HTA Area across the landing field. The great majority of buildings in the LTA Area are residential, just as they were historically. The area was originally developed for lighter-than-air activities in the late 1910s, serving as the location for the Airship School. A small area on the northern boundary of the historic district was the historic location of lighter-than-air operations. By the early 1930s, most LTA activities had been curtailed. A large number of brick duplexes were constructed at that time to house enlisted men. They are located on arced streets north and south of Clarke Avenue, the main route through the LTA Area. Additional housing has been constructed since the 1960s. There are also a number of contemporary recreational facilities located in the LTA Area (swimming pools, ball fields, etc.)

The only remaining buildings associated with LTA operations are also two of Langley's oldest buildings, the hydrogen plant (No. 1004) and the compressor plant (No. 1007), constructed in 1919. They are now surrounded by later historic and non-historic development. A huge airship/balloon hangar (420 feet long x 125 feet wide x 116 feet high) was located here from 1919 until 1947, when it was dismantled. It rivaled the Full-Scale Tunel in size.Substantial development of the LTA Area first occurred in the early 1920s. Construction associated with LTA activities included: a helium plant (1922, demolished), two houses for noncommissioned officers (1920-1921, No. 948 and No. 949), bachelor NCO quarters (demolished), 14 "temporary" NCO houses (demolished), six houses for officers of the Airship School (1922-1923, No. 868 and No. 869, four others demolished) and bachelor officers' quarters (Mabry Hall, demolished). The 19th century Lamington Plantation (demolished) was also located in the LTA Area. It housed most Langley Field commanders until the 1930s. Although Langley AFB has

classified the four remaining LTA residential buildings as substandard (Nos. 868, 869, 948, 949), their exterior and interior integrity and condition appear to be good. Substantial demolition in the LTA Area has left these four buildings as the only extant housing associated with LTA activities.

Historic construction in the LTA Area is concentrated in two adjacent sections of housing for enlisted men and their families, located north and south of Clarke Avenue. All of these buildings were built in the 1930s and are variations of two different house types. One type has Spanish Colonial Revival features; the second type is Classical Revival in style. All housing in these sections is constructed of brick and identical in scale and height. In 1931, 29 duplexes were constructed on the arc-shaped tier of streets facing the landing field, south of Clarke Avenue. Nine more were built in 1932. Three different variations of the two-story house type with Spanish Colonial Revival features were utilized for this group of buildings. Although very similar, some houses have gabled roofs (i.e.,No. 805), some have hipped roofs with a single hipped roof end pavilion (i.e., No. 808), and a number have hipped roofs with hipped roof pavilions on both end sections (i.e., No. 804). The NCO Club was completed in 1932 (No. 926) on the waterfront, just east of this residential section. Large new additions have been added to almost all of the building's original facades, including enclosure or removal of the porch on the waterfront side. The original interior appears to have been gutted. As a result, this building has lost its historic integrity. It is one of the few historic buildings in the Langley Field Historic District designated as a noncontributing resource. On the north side of Clarke Avenue is a horseshoe-shaped tier of streets with another group of similar duplexes. In 1932, eight of a new house type in the Classical Revival style and a large barracks for enlisted men (No. 801) were completed. Fifteen more of the Classical Revival houses were finished in 1934. Twenty-one brick garages were built in 1933-1934, and two stucco garages in 1940 (No. 858 and No. 870), completing the historic residential construction in the LTA Area.

The overall character of these housing areas is that of a neighborhood. Front and side yards are uniform in size, and rear service roads paralleling the main streets provide access to the garages. Shade trees planted in the street right of way have matured. There is a system of sidewalks and streetlights (historic and reproductions), as also found in the HTA Area. The interior and exterior integrity and condition of these buildings are good, except for incompatible replacement windows. The only notable alterations, other than windows, are pitched replacement roofs on the 21 garages that formerly had flat roofs.

Additional construction in the LTA Area is described below under the headings World War Two Temporary buildings and Noncontributing Resources (p. 11).

THE AIRFIELD
The airfield is an integral part of Langley Field's significance, and the locations of runways have been maintained since their original construction in 1917-1918. The main runways, flight line aprons, and some taxiways were paved between 1938 and 1945, although they have been repaved and rebuilt since that time. The historic district boundary was drawn to include the historic air field. Its central location links the HTA and LTA Area, and reflects its pivotal role in the development of Langley Field.

WORLD WAR II TEMPORARY BUILDINGS
Almost all of the massive program of temporary construction that was associated with World War II at Langley Field has been demolished. A small number of 1940s buildings are scattered in the HTA and LTA Areas. Most of them now have artificial siding, but they are designated as contributing resources because they still retain their historic character.

NONCONTRIBUTING RESOURCES
One factor responsible for the high degree of integrity found in the Langley Field Historic District is its low percentage of noncontributing resources, 24 percent. Most noncontributing resources were constructed after the historic district's period of significance. There are only a few historic buildings designated as noncontributing in the Inventory of Historic Resources because remodelling and new additions did not respect the buildings' historic character. As a result, their integrity has been lost. There are two historic cemetery sites associated with former plantations on land subsequently purchased for Langley Field. The 19th-century Sherwood cemetery (No. 437) is in the HTA Area in front of the Officers' Club. Another small cemetery is located in the LTA Area (next to No. 857). They date prior to the historic district's period of significance, and are not considered contributing resources because they are not associated Langley Field's development and areas of significance.

In the HTA Area, non-historic construction has a minimal effect on the district's historic character. There are only a few large contemporary buildings in the HTA Area. Facility No. 602 is the most incompatible with the historic district because of its large size, prominent location, and incompatible building materials. A substantial number of noncontributing resources are located in the NASA East Area. Most of these are small non-descript storage-type facilities on the waterfront side of Facility No. 720 (seaplane towing tank). The area has an industrial character and is buffered from the rest of the historic district by two large facilities, the Full-Scale Tunnel (No. 643) and the seaplane tow tank (No. 720). New construction in the LTA Area does not substantially impact its historic character. A 1966 highrise for housing is on the waterfront at the district's northeastern boundary, east of the main (historic) housing area. It is not accessed by the historic neighborhood's arced streets. A trailer court between the residential area and the landing field is not very visible from the main street through the LTA Area. A number of contemporary recreation facilities (ball fields and

associated buildings, pool, pier, running track) are located in grassy areas near the waterfront, between the housing area and the river bank, with minimal effect on the LTA Area's historic character.

A substantial number of noncontributing elements in the historic district are "utility vaults," constructed after 1947. In appearance, these small rectangular brick sheds are very similar to the utility vaults constructed prior to 1947, during the Army air arm's period of significance at Langley Field. As a result, noncontributing utility vaults have a neglible effect on the district's historic character. When these structures are not included in the total of noncontributing resources, that percentage is reduced from 24 percent to 21 percent.

SUMMARY

The Langley Field Historic District has 379 resources; 290 buildings, 86 structures, two sites and one object--76 percent contribute to the character of the historic district and 24 percent are noncontributing resources. All resources that retain their integrity and date from Langley Field's period of significance (1917-1947, Army air arm), (1917-1958 NASA/LMAL) contribute to the character of the district. Historic Langley Field has a high degree of integrity, and the wide range of historic resources and property types illustrates its unique role in the development of American military and civil aviation.

INVENTORY OF HISTORIC RESOURCES
LANGLEY FIELD

	FACILITY NUMBER	RESOURCE	DATE		RESOURCE TYPE
1.	402	billboard	1965	Noncontributing	Structure
2.	404	road bridge	1935	Contributing	Structure
3.	407	telephone exchange	1956	Noncontributing	Building
4.	408	billboard	1959	Noncontributing	Structure
5.	409	swimming pool bath house	1939	Contributing	Building
6.	410	swimming pool	1939	Contributing	Structure
7.	412	Officers' Club	1935	Contributing	Building
8.	413	seawall	1931	Contributing	Structure

9.	414	Officers Quarters 153 Benedict Avenue	1934	Contributing	Building
10.	415	Officers Quarters 152 Benedict Avenue	1934	Contributing	Building
11.	416	utility vault	1958	Noncontributing	Structure
12.	417	Officers Quarters 151 Benedict Avenue	1934	Contributing	Building
13.	418	Officers Quarters 150 Benedict Avenue	1934	Contributing	Building
14.	419	gazebo	1960	Noncontributing	Structure
15.	421	Officers Quarters 149 Benedict Avenue	1934	Contributing	Building
16.	422	Officers Quarters 148 Benedict Avenue	1934	Contributing	Building
17.	423	Officers Quarters 49 A&B Bryant Avenue	1932	Contributing	Building
18.	424	Officers Quarters 154 Benedict Avenue	1934	Contributing	Building
19.	425	utility vault	1958	Noncontributing	Structure
20.	426	Officers Quarters 50 A&B Eagan Avenue	1931	Contributing	Building
21.	428	Officers Quarters 144 A&B Wright Avenue	1934	Contributing	Building
22.	429	Officers Quarters 51 A&B Eagan Avenue	1931	Contributing	Building
23.	430	Officers Quarters 143 A & B Benedict Avenue	1934	Contributing	Building
24.	431	Officers Quarters 52 A & B Glover Avenue	1931	Contributing	Building
25.	432	sewage pump station	1931	Contributing	Structure

26.	434	Officers Quarters 53 Dodd Boulevard	1932	Contributing	Building
27.	435	Officers Quarters 141 A & B Glover Avenue	1931	Contributing	Building
28.	436	Officers Quarters 142 A & B Glover Avenue	1931	Contributing	Building
29.	437	Cemetery	19th century	Noncontributing	Site
30.	437	Cemetery wall	1940	Contributing	Structure
31.	439	marble marker	After 1947	Noncontributing	Object
32.	440	bus shelter	1953	Noncontributing	Building
33.	441	Red Cross	Before 1945	Contributing	Building
34.	442	Shoppette	1940	Contributing	Building
35.	443	utility vault	1980	Noncontributing	Structure
36.	445	Officers Quarters 28 A & B Glover Avenue	1931	Contributing	Building
37.	446	Officers Quarters 29 A & B Glover Avenue	1931	Contributing	Building
38.	447	Officers Quarters 30 Dodd Boulevard	1932	Contributing	Building
39.	448	Dodd Hall 32 Dodd Boulevard	1919	Contributing	Building
40.	449	Officers Quarters 31 A & B Wright Avenue	1931	Contributing	Building
41.	450	Officers Quarters 32 A & B Eagan Avenue	1931	Contributing	Building
42.	451	Officers Quarters 36 Dodd Boulevard	1932	Contributing	Building

43.	452	Officers Quarters 35 A & B Dodd Boulevard	1931	Contributing	Building
44.	453	Officers Quarters 34 A & B Bryant Avenue	1931	Contributing	Building
45.	454	Officers Quarters 33 A & B Eagan Avenue	1931	Contributing	Building
46.	455	Officers Quarters 27 A & B Eagan Avenue	1920	Contributing	Building
47.	456	Officers Quarters 26 A & B Eagan Avenue	1920	Contributing	Building
48.	458	Officers Quarters 25 A & B Eagan Avenue	1920	Contributing	Building
49.	459	residential garage	1934	Contributing	Building
50.	460	Officers Quarters 23 A & B Eagan Avenue	1920	Contributing	Building
51.	461	Officers Quarters 22 A & B Glover Avenue	1920	Contributing	Building
52.	462	Officers Quarters 24 A & B Glover Avenue	1920	Contributing	Building
53.	463	residential garage	1934	Contributing	Building
54.	467	Credit Union	1982	Noncontributing	Building
55.	472	Lawson Hall	1919	Contributing	Building
56.	475	Memorial Park (airplanes)	1983	Noncontributing	Structure
57.	500	Post Office	1942	Contributing	Building
58.	502	Officers Quarters 39 A & B Bryant Avenue	1931	Contributing	Building
59.	503	Officers Quarters 40 Eagan Avenue	1932	Contributing	Building

60.	504	Officers Quarters 1931 41 A & B Tyndal Place	Contributing	Building
61.	505	Officers Quarters 1931 42 A & B Tyndal Place	Contributing	Building
62.	506	Officers Quarters 1932 44 Eagan Avenue	Contributing	Building
63.	507	Officers Quarters 1931 43 A & B Bowen Street	Contributing	Building
64.	508	Officers Quarters 1932 38 A & B Bryant Avenue	Contributing	Building
65.	509	utility vault 1973	Noncontributing	Structure
66.	510	Officers Quarters 1931 37 A & B Dodd Boulevard	Contributing	Building
67.	512	Officers Quarters 1932 47 A & B Bowen Street	Contributing	Building
68.	513	Officers Quarters 1931 46 A & B Bowen Street	Contributing	Building
69.	514	Officers Quarters 1932 45 Eagan Avenue	Contributing	Building
70.	519	residential garage 1934	Contributing	Building
71.	520	Chapel 1935	Contributing	Building
72.	521	bus shelter 1953	Noncontributing	Building
73.	523	residential garage 1934	Contributing	Building
74.	524	Officers Quarters 1918 15 A & B Eagan Avenue	Contributing	Building
75.	525	Officers Quarters 1918 17 A & B Eagan Avenue	Contributing	Building
76.	526	Officers Quarters 1918 19 A & B Eagan Avenue	Contributing	Building
77.	527	Officers Quarters 1918	Contributing	Building

		21 A & B Eagan Avenue		
78.	530	Officers Quarters 1918 20 A & B Eagan Avenue	Contributing	Building
79.	531	Officers Quarters 1918 18 A & B Eagan Avenue	Contributing	Building
80.	532	Officers Quarters 1918 16 A & B Eagan Avenue	Contributing	Building
81.	533	Officers Quarters 1918 14 A & B Eagan Avenue	Contributing	Building
82.	534	Officers Quarters 1918 12 A & B Eagan Avenue	Contributing	Building
83.	535	Officers Quarters 1918 10 A & B Eagan Avenue	Contributing	Building
84.	536	Officers Quarters 1918 8 A & B Eagan Avenue	Contributing	Building
85.	537	Officers Quarters 1918 6 A & B Plumb Street	Contributing	Building
86.	538	Officers Quarters 1918 7 A & B Nealy Avenue	Contributing	Building
87.	539	Officers Quarters 1918 9 A & B Eagan Avenue	Contributing	Building
88.	541	Officers Quarters 1918 11 A & B Nealy Avenue	Contributing	Building
89.	542	Officers Quarters 1918 13 A & B Thompson Street	Contributing	Building
90.	543	residential garage 1934	Contributing	Building
91.	544	residential garage 1934	Contributing	Building
92.	546	Austin Hall 1924 (barracks)	Contributing	Building
93.	548	Officers Quarters 1934 155 Benedict Avenue	Contributing	Building

94.	549	Officers Quarters 156 Benedict Avenue	1934	Contributing	Building
95.	550		1943	Noncontributing	Building
96.	551	Officers Quarters 48 A & B Bowen Street	1931	Contributing	Building
97.	554	Officers Quarters 147 Benedict Avenue	1934	Contributing	Building
98.	555	utility vault	1955	Noncontributing	Structure
99.	556	Officers Quarters 146 Benedict Avenue	1934	Contributing	Building
100.	557	Officers Quarters 145 Benedict Avenue	1934	Contributing	Building
101.	558	Hospital	1932	Contributing	Building
102.	560		1952	Noncontributing	Building
103.	566	Medical	1934	Contributing	Building
104.	567	Medical Housing	1931	Contributing	Building
105.	568	storage	1956	Noncontributing	Building
106.	569	residential garage	1933	Contributing	Building
107.	570	Medical Housing	1931	Contributing	Building
108.	571	pier	1960	Noncontributing	Structure
109.	580	Wind Tunnel No.1 AWT-NACA	1920	Contributing	Building
110.	581	Substation	1940	Contributing	Structure
111.	582	Compressor Station NACA	1940	Contributing	Building
112.	582A	Low Turbulence Pressure Tunnel NACA	1940	Contributing	Building

113.	583	Transonic Tunnel NACA	1938	Contributing	Building
114.	583A	Maintenance Bldg. NACA	1929	Contributing	Building
115.	584	Utility Bldg. NACA	1935	Contributing	Building
116.	585	Vertical Wind Tunnel-NACA	1934	Contributing	Structure
117.	586	Service Bldg.	1926	Contributing	Building
118.	587	NACA Laboratory	1918	Contributing	Building
119.	590		1943	Contributing	Building
120.	591	Elementary School	1939	Contributing	Building
121.	592	utility vault	1949	Noncontributing	Structure
122.	593	utility vault	1962	Noncontributing	Structure
123.	596	Gas station Reclamation building	1920	Noncontributing	Building
124.	602	Administration	1969	Noncontributing	Building
125.	604	barbeque pit	1967	Noncontributing	Structure
126.	605	Central Heating Plant-Officers Area	1934	Contributing	Building
127.	606	Truck shed	1920	Contributing	Building
128.	607	Radio building	1931	Contributing	Building
129.	608	bridge walkway	1956	Noncontributing	Structure
130.	610	pier	1932	Contributing	Structure
131.	611	boat ramp	1955	Noncontributing	Structure
132.	615	Maintenance shop	1942	Contributing	Building
133.	616	Water tank	1942	Contributing	Structure

134.	617	QM Maintenance	1934	Contributing	Building
135.	619	miscellaneous	1982	Noncontributing	Building
136.	620	Water tank	1921	Contributing	Structure
137.	621	Quartermaster Garage	1932	Contributing	Building
138.	622	Boilerhouse	1927	Contributing	Building
139.	623	Technical Stores	1920	Contributing	Building
140.	625	Blueprint Room	1933	Contributing	Building
141.	626	electrical substation	1932	Contributing	Building
142.	628	utility vault	1932	Contributing	Structure
143.	630	miscellaneous	1982	Noncontributing	Building
144.	633	Seaplane hangars	1921	Contributing	Building
145.	634	utility vault	1962	Noncontributing	Structure
146.	635	Barracks	1932	Contributing	Building
147.	655	Central Heating Plant-Barracks Area	1932	Contributing	Building
148.	656	sewage pump station	1931	Contributing	Structure
149.	657	Theater	1933	Contributing	Building
150.	658	Gymnasium	1933	Contributing	Building
151.	660	bus shelter	1953	Noncontributing	Building
152.	661	Machine Shop and Commissary	1918	Contributing	Building
153.	662	utility vault	1940	Contributing	Structure
154.	664	Barracks	1932	Contributing	Building
155.	665	utility vault	1950	Noncontributing	Structure

156.	669	Barracks	1932	Contributing	Building
157.	671	Barracks	1932	Contributing	Building
158.	680	utility vault	1940	Contributing	Structure
159.	681	Barracks	1932	Contributing	Building
160.	684	residential garage	1934	Contributing	Building
161.	685	residential garage	1934	Contributing	Building
162.	688	Officers Quarters 5 A & B Plumb Street	1918	Contributing	Building
163.	689	Officers Quarters 4 A & B Eagan Avenue	1918	Contributing	Building
164.	690	Officers Quarters 3 A & B Eagan Avenue	1918	Contributing	Building
165.	691	Officers Quarters 2 A & B Eagan Avenue	1918	Contributing	Building
166.	693	Army Aeronautical Laboratory	1919	Contributing	Building
167.	695	electric power station	1961	Noncontributing	Structure
168.	700	Fire Station	1933	Contributing	Building
169.	703	Barracks	1932	Contributing	Building
170.	706	utility vault	1955	Noncontributing	Structure
171.	707	pump station	1953	Noncontributing	Structure
172.	711	bus shelter	1953	Noncontributing	Building
173.	712	electrical switch station	1940	Contributing	Structure
174.	714	Guard House	1932	Contributing	Building
175.	733	ILS Localizer	1954	Noncontributing	Structure

176.	740	electrical power station	1954	Noncontributing	Structure
177.	741		1972	Noncontributing	Building
178.	744	Police Operations	1953	Noncontributing	Building
179.	747	Police Operations	1970	Noncontributing	Building
180.	750	Hangar	1932	Contributing	Building
181.	751	Hangar	1932	Contributing	Building
182.	752	Hangar	1932	Contributing	Building
183.	753	Hangar	1932	Contributing	Building
184.	754	Hangar	1932	Contributing	Building
185.	755	Hangar	1932	Contributing	Building
186.	756	Hangar	1932	Contributing	Building
187.	757	Hangar	1929	Contributing	Building
188.	760	fuel building	1976	Noncontributing	Building
189.	762	Police Operations	1976	Noncontributing	Building
190.	763	Police Operations	1985	Noncontributing	Building
191.	764	Administration	1988	Noncontributing	Building
192.	768		1932	Contributing	Building
193.	771		1943	Contributing	Building
194.	774		1972	Noncontributing	Building
195.	775		1932	Contributing	Building
196.	777	Hangar	1919	Contributing	Building
197.	778	electrical substation	1964	Noncontributing	Structure
198.	780	Radome	1968	Noncontributing	Structure

199.	781	Hangar	1918	Contributing	Building
200.	782		1942	Noncontributing	Building
201.	784	Parachute building	1931	Contributing	Building
202.	788	Photography Laboratory	1932	Contributing	Building
203.	801	Barracks	1932	Contributing	Building
204.	802	bus shelter	1961	Noncontributing	Building
205.	803	residential garage	1933	Contributing	Building
206.	804	NCO Housing 241 A & B Ryan Avenue	1931	Contributing	Building
207.	805	NCO Housing 240 A & B Ryan Avenue	1931	Contributing	Building
208.	806	NCO Housing 239 A & B Ryan Avenue	1932	Contributing	Building
209.	807	NCO Housing 238 A & B Ryan Avenue	1932	Contributing	Building
210.	808	NCO Housing 237 A & B Ryan Avenue	1931	Contributing	Building
211.	809	NCO Housing 236 A & B Ryan Avenue	1931	Contributing	Building
212.	810	residential garage	1933	Contributing	Building
213.	811	tennis court	1975	Noncontributing	Structure
214.	813	trailer court		Noncontributing	Structure
215.	814	church	1942	Contributing	Building
216.	815	NCO Housing 233 A & B Gray Avenue	1931	Contributing	Building
217.	816	NCO Housing 232 A & B Gray Avenue	1931	Contributing	Building

218.	817	residential garage	1933	Contributing	Building
219.	818	NCO Housing 208 A & B Harris Avenue	1932	Contributing	Building
220.	819	NCO Housing 234 A & B Helm Avenue	1932	Contributing	Building
221.	820	NCO Housing 231 A & B Gray Avenue	1931	Contributing	Building
222.	821	NCO Housing 230 A & B Gray Avenue	1931	Contributing	Building
223.	822	residential garage	1933	Contributing	Building
224.	823	NCO Housing 229 A & B Gray Avenue	1931	Contributing	Building
225.	824	utility vault	1955	Noncontributing	Structure
226.	825	NCO Housing 228 A & B Gray Avenue	1931	Contributing	Building
227.	826	NCO Housing 227 A & B Gray Avenue	1931	Contributing	Building
228.	827	NCO Housing 226 A & B Gray Avenue	1931	Contributing	Building
229.	828	residential garage	1933	Contributing	Building
230.	829	NCO Housing 225 A & B Gray Avenue	1931	Contributing	Building
231.	830	NCO Housing 224 A & B Gray Avenue	1931	Contributing	Building
232.	831	NCO Housing 216 A & B Harris Avenue	1931	Contributing	Building
233.	832	residential garage	1933	Contributing	Building
234.	833	NCO Housing 215 A & B Harris Avenue	1931	Contributing	Building
235.	834	residential garage	1933	Contributing	Building

236.	835	NCO Housing 214 A & B Harris Avenue	1931	Contributing	Building
237.	836	residential garage	1933	Contributing	Building
238.	838	NCO Housing 213 A & B Harris Avenue	1931	Contributing	Building
239.	839	residential garage	1933	Contributing	Building
240.	840	NCO Housing 212 A & B Harris Avenue	1931	Contributing	Building
241.	841	residential garage	1933	Contributing	Building
242.	842	NCO Housing 211 A & B Harris Avenue	1931	Contributing	Building
243.	843	NCO Housing 210 A & B Harris Avenue	1931	Contributing	Building
244.	844	residential garage	1933	Contributing	Building
245.	845	NCO Housing 209 A & B Harris Avenue	1932	Contributing	Building
246.	846	bus shelter	1978	Noncontributing	Building
247.	848	NCO Housing 207 A & B Harris Avenue	1931	Contributing	Building
248.	849	NCO Housing 206 A & B Harris Avenue	1931	Contributing	Building
249.	850	residential garage	1933	Contributing	Building
250.	851	NCO Housing 205 A & B Harris Avenue	1931	Contributing	Building
251.	852	NCO Housing 204 A & B Harris Avenue	1931	Contributing	Building
252.	853	residential garage	1933	Contributing	Building
253.	854	NCO Housing 203 A & B Harris Avenue	1931	Contributing	Building

254.	856.	NCO Housing 202 A & B Harris Avenue	1931	Contributing	Building
255.	857	NCO Housing 201 A & B Harris Avenue	1931	Contributing	Building
256.	858	residential garage	1940	Contributing	Building
257.		Cemetery	18th century	Noncontributing	Site
258.	864	utility vault	1940	Contributing	Structure
259.	865	bus shelter	1987	Noncontributing	Building
260.	868	LTA Officers Quarters 99 Clarke Avenue	1923	Contributing	Building
261.	869	LTA Officers Quarters 100 Clarke Avenue	1923	Contributing	Building
262.	870	residential garage	1940	Contributing	Building
263.	873	NCO Housing 223 A & B Gray Avenue	1932	Contributing	Building
264.	874	NCO Housing 222 A & B Gray Avenue	1932	Contributing	Building
265.	875	NCO Housing 221 A & B Gray Avenue	1932	Contributing	Building
266.	876	NCO Housing 220 A & B Gray Avenue	1932	Contributing	Building
267.	877	utility vault	1955	Noncontributing	Structure
268.	878	NCO Housing 219 A & B Gray Avenue	1932	Contributing	Building
269.	879	utility vault	1942	Contributing	Structure
270.	880	residential garage	1933	Contributing	Building
271.	881	NCO Housing	1932	Contributing	Building

		218 A & B Harris Avenue			
272.	882	NCO Housing 217 A & B Harris Avenue	1931	Contributing	Building
273.	883	residential garage	1933	Contributing	Building
274.	890	Aero Club Complex	1952	Noncontributing	Building
275.	891	Aero Club Complex	1955	Noncontributing	Building
276.	893	Aero Club Complex	1955	Noncontributing	Building
277.	894	Aero Club	1941	Contributing	Building
278.	901	pier	1943	Contributing	Structure
279.	902	swimming pool	1954	Noncontributing	Structure
280.	903	latrine	1958	Noncontributing	Building
281.	904	wading pool	1959	Noncontributing	Structure
282.	905	swimming pool bath house	1959	Noncontributing	Building
283.	906	utility vault	1949	Noncontributing	Structure
284.	912	electric switch station	1940	Contributing	Structure
285.	923	bus shelter	1966	Noncontributing	Building
286.	925	pier	1960	Noncontributing	Structure
287.	926	NCO Club	1932	Noncontributing	Building
288.	928		1965	Noncontributing	Building
289.	935	electric switch station	1952	Noncontributing	Structure
290.	937	utility vault	1940	Contributing	Structure
291.	938	sewage pump station	1931	Contributing	Structure
292.	942	picnic pavilion	1989	Noncontributing	Structure

293.	943	storage	1985	Noncontributing	Building
294.	945	high rise housing	1966	Noncontributing	Building
295.	948	LTA NCO Bachelors Quarters-78 Deford Street	1921	Contributing	Building
296.	949	LTA NCO Bachelors Quarters-77 Deford Street	1921	Contributing	Building
297.	950	NCO Housing 266 A & B Watts Avenue	1934	Contributing	Building
298.	951	NCO Housing 267 A & B Watts Avenue	1934	Contributing	Building
299.	956	NCO Housing 268 A & B Watts Avenue	1934	Contributing	Building
300.	957	NCO Housing 269 A & B Watts Avenue	1934	Contributing	Building
301.	958	utility vault	1940	Contributing	Structure
302.	959	residential garage	1934/1935	Contributing	Building
303.	960	NCO Housing 270 A & B Watts Avenue	1934	Contributing	Building
304.	965		1942	Noncontributing	Building
305.	969	NCO Housing 271 A & B Watts Avenue	1934	Contributing	Building
306.	970	residential garage	1934/1935	Contributing	Building
307.	971	NCO Housing 272 A & B Watts Avenue	1934	Contributing	Building
308.	972	residential garage	1933	Contributing	Building
309.	974	NCO Housing 273 A & B Watts Avenue	1934	Contributing	Building

310.	975	NCO Housing 274 A & B Watts Avenue	1932	Contributing	Building
311.	976	NCO Housing 275 A & B Watts Avenue	1932	Contributing	Building
312.	977	utility vault	1940	Contributing	Structure
313.	978	residential garage	1933	Contributing	Building
314.	980	NCO Housing 276 A & B Watts Avenue	1932	Contributing	Building
315.	981	residential garage	1933/1935	Contributing	Building
316.	982	NCO Housing 277 A & B Murray Court	1932	Contributing	Building
317.	983	NCO Housing 278 A & B Murray Court	1932	Contributing	Building
318.	985	NCO Housing 279 A & B Murray Court	1934	Contributing	Building
319.	986	NCO Housing 280 A & B Watts Avenue	1932	Contributing	Building
320.	987	NCO Housing 281 A & B Watts Avenue	1934	Contributing	Building
321.	988	NCO Housing 282 A & B Watts Avenue	1934	Contributing	Building
322.	989	NCO Housing 283 A & B Watts Avenue	1934	Contributing	Building
323.	991	NCO Housing 284 A & B Watts Avenue	1934	Contributing	Building
324.	993	residential garage	1934/1935	Contributing	Building
325.	995	NCO Housing 285 A & B Murray Court	1934	Contributing	Building
326.	997	NCO Housing 286 A & B Murray Court	1934	Contributing	Building

327.	998	utility vault	1940	Contributing	Structure
328.	999	Chapel	1942	Contributing	Building
329.	1000	Water tank	1930	Contributing	Structure
330.	1001	greenhouse	1934	Contributing	Building
331.	1003	utility vault	1940	Contributing	Structure
332.	1004	Generator Gas Plant	1917	Contributing	Building
333.	1006	office trailers	1980s	Noncontributing	Building
334.	1007	Compressor Gas	1917	Contributing	Building
335.	1008	skeet building	1964	Noncontributing	Structure
336.	1010	skeet building	1964	Noncontributing	Structure
337.	1018		1940	Contributing	Building
338.	6005	Apron	1941	Contributing	Structure
339.	6010	Apron	1938	Contributing	Structure
340.	7025	Runway	1938	Contributing	Structure
341.	7030	Taxiway	1944	Contributing	Structure
342.	7040	Taxiway	1944	Contributing	Structure
343.	7095	Taxiway	1941	Contributing	Structure
344.	7100	Taxiway	1945	Contributing	Structure
345.	7105	Taxiway	1938	Contributing	Structure
346.	17035	Runway	1944	Contributing	Structure
347.		Roadway System	1917	Contributing	Structure

NASA EAST AREA - AIR FORCE FACILITIES

348.	636	storage	1980s	Noncontributing	Structure

349.	721	fuel pier	1953	Noncontributing	Structure
350.	722	LF unload	1964	Noncontributing	Structure
351.	724	storage, liquid ox. sanitary sewage	1943	Contributing	Building
352.	726		1967	Noncontributing	Building
353.	727		1963	Noncontributing	Structure
354.	728	BE storage CV facility	1957	Noncontributing	Building
355.	729	TST cell	1953	Noncontributing	Structure
356.	730	BE storage CV facility	1957	Noncontributing	Structure
357.	731	storage, liquid ox.	1968	Noncontributing	Structure
358.	732	storage, liquid ox.	1985	Noncontributing	Building
359.	734	test cell	1974	Noncontributing	Structure
360.	735	shp acft, gen purp	1988	Noncontributing	Building
361.	738	L/fuel stand,unload	1964	Noncontributing	Structure

NASA EAST AREA - NASA FACILITIES

362.	636A	satellite dish	1980s	Noncontributing	Structure
363.	640	8-Foot Transonic Pressure Tunnel	1953	Contributing	Building
364.	641	8-Foot High Speed Tunnel/TPT Offices	1936	Contributing	Building
365.	641A	storage		Noncontributing	Building
366.	641B	cooling tower		Noncontributing	Structure
367.	642	Back River Substation	1941	Contributing	Structure

368.	643	Full-Scale Tunnel (30x60-Foot Tunnel)	1930	Contributing	Building
369.	644	Free Flight Tunnel (12-Foot Low Speed Tunnel)	1939	Contributing	Building
370.	645	20-Foot Free-Spinning Tunnel	1941	Contributing	Building
371.	645A	Spin Research Office	1978	Noncontributing	Building
372.	646	Free-Spinning Wind Tunnel/Dynamic Tunnel Building	1934	Contributing	Building
373.	647	East Shop	1939	Contributing	Building
374.	648A	TDT Cooling Tower	1982	Noncontributing	Structure
375.	648	19-Foot Pressure Tunnel (Transonic Dynamics Tunnel)	1938	Contributing	Building
376.	650	Mathis Road Substation	1938	Contributing	Structure
377.	720	Tank No.1 tank extension and office building	1931 1937	Contributing	Building
378.	720A	Impact Basin (Dynamic Model Shop)	1943	Contributing	Building
379.	720B	Tank No.2	1942	Contributing	Building

Statement of Significance

The Langley Field Historic District in Hampton, Virginia, is the most architecturally and historically significant Army airfield in the United States, a premier position attributed to its unique role in the development of American military and civil aviation. It is eligible for the National Register of Historic Places under National Register Criteria A, B, and C, and has significance in the following areas: military, science, engineering, architecture, education, invention, commerce, industry, transportation, communications, social history, community planning and development, and landscape architecture.

The establishment of Langley Field in 1917, as the Aeronautical Experimental Station and Proving Ground for the U.S. Army's fledgling air "arm," was unique. The purchase of the land in 1916 was the Federal government's first for civil or military aviation purposes. The National Advisory Committee for Aeronautics (NACA) participated in the Army's site search for its new experimental station. NACA, an independent government agency for the advancement of aeronautics, had expectations of establishing the Federal government's first aeronautical laboratory at the Army's experimental station. Langley Field's original purpose changed, however, before permanent construction could be completed. The United States' declaration of war in April 1917 caused a major change of direction for Army aviation, which, in turn, altered the Army's plans for Langley Field. Experimental activities planned for Langley were transferred to Ohio to get them underway immediately. During the war, Langley Field was primarily used for flying training, and subsequently became a regular Army airfield, part of a nationwide network of military airfields. As a result, Langley Field assumed a pivotal historic role in the development of American military aviation, the organizational development of the air arm of the U.S. Army, and the eventual establishment of the United States Air Force as a separate arm of the military services. Major developments in Army aviation doctrine, education, and training also occurred at Langley Field. The period of significance for resources associated with the Army air arm at Langley Field is 1917-1947.

Langley Field's historic role in the development of aeronautics in America was unique. It was the site of the first national aeronautical research laboratory established by the United States Government. The Langley Memorial Aeronautical Laboratory (LMAL), formally dedicated in June 1920, was NACA's first laboratory and the Federal government's only aeronautical laboratory for more than 20 years. The scope of its fundamental research programs ranged over the entire field of the science of aeronautics: the design, construction, and operation of aircraft. Unique and outstanding research programs in the 1920s and 1930s established LMAL's international reputation as the world's premier aeronautical laboratory, "primarily responsible for nursing U.S. aviation from infancy to

world leadership."[4] In addition, its cutting-edge research usually required the invention of new research facilities, which LMAL scientists and engineers had to design and build themselves. The wind tunnel complex that enabled most of these advances was the largest in the world in the late 1920s and early 1930s. Several of these facilities were historically the only ones of their type in the world. Three of LMAL's wind tunnels were designated National Historic Landmarks in 1985 for their contributions to the American space program. The period of significance for resources associated with NACA and the Langley Memorial Aeronautical Laboratory is 1917-1958.

The combination of Langley's significance in military aviation and its association with the Langley Memorial Aeronautical Laboratory makes Langley Field an integral part of the story of American aviation. Developments in American history, and even world history, that supported and/or accompanied the growth of American civil and military aviation are wide-ranging, and give the Langley Field Historic District significance in a large number of areas. The areas of significance associated with both the Army air arm and NACA/LMAL are military, engineering, architecture, transportation, education, invention, commerce, communications, and social history. Significance in science and industry is associated with NACA/LMAL only. Community planning and development and landscape architecture are associated with the Army air arm at Langley Field.

The historic context developed for this study integrates the early histories of the Army air arm and the National Advisory Committee for Aeronautics. Developments in Army aviation organization, doctrine, and training are encompassed. The context also examines NACA in relationship to its mother laboratory, the Langley Memorial Aeronautical Laboratory. It emphasizes major trends in American aeronautics, and NACA/LMAL's research programs and major facilities that accompanied those trends. **American Aviation and Aeronautics in the Early 20th Century: The Army Air Arm and the National Advisory Committee for Aeronautics** provides a context for assessing the history of Langley Field in relationship to the broad historical developments in Army aviation and American aeronautics.

A chronological history of Langley Field follows the context (pages 63-99). It may appear lengthy, but it is a selective narration of the district's history, focusing on events, activities, people, and characteristics that contribute to its broad significance. Langley Field's earliest history (1916-1921) is discussed in particular detail because of misconceptions about this period that, repeated over the years, have come to be regarded as facts. Another purpose is to provide a history of Langley Field that combines activities of the Army air arm and NACA's Langley Memorial Aeronautical Laboratory. Such an

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[4]James Schultz, **Winds of Change**, (Washington, DC: National Aeronautics and Space Administration, 1992).

effort apparently has not been undertaken for the last 50 years; more recent Air Force and NASA histories of Langley Field focus on their own organizations. The remarkable significance of this place—the Langley Field Historic District—is of national importance and encompasses the early histories of both Federal agencies.

AMERICAN AVIATION AND AERONAUTICS IN THE EARLY 20TH CENTURY: THE ARMY AIR ARM AND THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

The world's first successful powered flight of an airplane on December 17, 1903 was not followed immediately by Federal acknowledgment of the significance of aviation, civil or military. News of the Wright brothers' accomplishment was met initially with great skepticism. It was not until September 1908 that powered flight became an accepted fact, when almost 1,000 people witnessed the Wright brothers' well-publicized flights in Fort Myer, Virginia. Even so, aviation's great advantages and possibilities, taken for granted today, had yet to be conceived in the early years of the 20th century.

The Federal government's interest in aviation was generally lacking for more than a decade after the first flight. Military aviation was established initially in the U.S. Army Signal Corps in August 1907 as a minor activity in the office of the Army's Chief Signal Officer. The Aeronautical Division had one officer and two enlisted men, and responsibilities to "take charge of all matters pertaining to military ballooning, air machines and all kindred subjects." The Chief Signal Officer requested bids for a flying machine in December 1907. Specifications required it to have a speed of 40 miles per hour, to carry two people, and to be capable of a one-hour flight. There were to be three trials to test for speed. Army officials were criticized for specifying flight performances that could not possibly be met, and no bids were expected to be submitted.[5] On February 10, 1908, the government signed a contract with the Wright brothers. They delivered the first Army plane at Fort Myer, Virginia in August 1908. It was the demonstration tests of this airplane that convinced the public that powered flight had been achieved. Delivery of the machine was postponed until the following summer due to an accident during the demonstration tests. Signal Corps Airplane No. 1 was formally accepted on August 2, 1909.

Congress made its first appropriation for Army aeronautics in March 1911, $125,000 for the 1912 fiscal year. Some of these funds were used immediately to buy five more airplanes; three were Wright Type Bs, and two were made by the Curtiss company. The planes were delivered to Fort Sam Houston, Texas, where the Army's first plane had relocated in February 1910. In the early days of flying, weather was the most important consideration, so the Army's small group

[5]Juliette A. Hennessy, **The United States Army Air Arm** (Washington, D.C.: Office of Air Force History, 1985), 27.

of airmen had flown south. The appropriation for 1912 also enabled establishment of the Army's first real flying school. The Army Quartermaster leased and prepared a field at College Park, Maryland, and the planes arrived from Fort Sam Houston in July 1911. This was the center of Army aviation until the end of the year, and it was primarily used to teach flying. Experimentation with radiotelegraphy, photography, automatic weapons firing, signaling systems, and bombing devices was also conducted.[6] The school relocated to Augusta, Georgia for the winters of 1911-1912 and 1912-1913. The Curtiss planes and pilots, however, spent the winter of 1912-1913 at the flying school established by Glen Curtiss on North Island, San Diego, California. The Signal Corps Aviation School was established there in December 1912, and this location became the Army's first permanent aviation school.[7]

On July 18,1914, an Aviation Section was established in the Army Signal Corps to promote the Signal Corps' aeronautical work. The new organization received an appropriation of $250,000, twice as much as any previous year. In addition to personnel already on aviation duty with the Signal Corps, 60 officers and 260 enlisted men were authorized. Aviation Section responsibilities included operating and supervising the operation of all military aircraft, and training of officers and enlisted men in military aviation. Components of the Section were the Aeronautical Division, the Signal Corps Aviation School at San Diego, and two aero squadrons, one on duty in Texas, and one in the Philippines. Between 1909 and 1915, the Signal Corps purchased 59 planes. Only 23 were still in service in January 1916.[8]

The first significant expansion of Army aviation was authorized by the National Defense Act of 1916 (June 3, 1916). The Act increased personnel from 60 to 148 officers, and it provided for a Signal Officers Reserve Corps and a Signal Enlisted Reserve Corps of 297 officers and 2,000 enlisted, to be trained under direction of the Aviation Section. The war in Europe led Congress to appropriate $13,281,666 for military aeronautics on August 29, 1916. In addition, $600,000 was appropriated for the Signal Corps to purchase its first

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[6]Jerold E. Brown, **Where Eagles Land-Planning and Development of U.S. Army Airfields, 1910-1941** (New York: Greenwood Press, 1990), 18.

[7]The College Park school closed in November 1912 when the pilots and planes moved to Augusta and San Diego for the winter, but they never returned. The College Park lease expired in 1913 and the station was abandoned. Hennessy, 73. The army received permission from the owner in 1913 to use part of North Island and construct some temporary buildings, but purchase of the land was not authorized by Congress until July 1919. Hennessy, 91.

[8]Hennessy, **Army Air Arm**, 156.

land for aviation purposes. This was the only legislative act to provide specifically for such a land purchase prior to World War I. Half of this amount was to purchase a site for the Aviation School at San Diego, and $300,000 was for a second field, "to be purchased, condemned or donated to the Government."[9] This appropriation finally gave the Signal Corps sufficient funds to develop military aviation.

The National Advisory Committee for Aeronautics was established on March 3, 1915, "to supervise and direct the scientific study of the problems of flight, with a view to their practical solution." This committee originated from efforts by aeronautical proponents who had sought establishment of a national aeronautical laboratory since 1910. European aviation advances and the potential for U.S. involvement in the Great War were largely responsible for the creation of the National Advisory Commmittee for Aeronautics (NACA) as an independent agency in 1915, as was the leadership provided by Charles Walcott, director of the Smithsonian Institution. An aeronautical research laboratory was the real goal of Walcott's group and its predecessors. They saw the establishment of this advisory committee (NACA and/or the Committee) as an important step to their goal, the best that could be accomplished under prevailing political circumstances. NACA's enabling legislation was finally passed, but as a rider on the naval appropriations bill for 1916.

> An Advisory Committee for Aeronautics is hereby established, and the President is authorized to appoint not to exceed twelve members, to consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; together with not more than five additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences.

The Committee stated at one of its first meetings that "one of the first and most important steps. . . is the provision and equipment of a flying field," and it "expressed hope that land . . . could be found on an existing Government reservation."[10] NACA's organic legislation provided no funds for this purpose, but it did allow for such a laboratory.

> In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the

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[9]Brown, "Eagles Roost," 62 and 55.

[10]Ibid., 60.

committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories.

NACA was appropriated $53,580 for lab construction on August 29, 1916, but no funds were provided for purchasing or developing a laboratory site. Committee members were aware of the Army's $300,00 appropriation for a flying field, planned to be an experimental station and proving ground. They apparently saw the project as their best opportunity for a laboratory location, and specific actions to establish a joint civil-military experimental field on the Army's proposed site were initiated by NACA. Efforts to advance civil and military aviation coincided at a site eventually known as Langley Field. The early histories of the Army's air arm and NACA are integral parts of the history of Langley Field, and the history of Langley Field is a key element in the story of American military and civil aviation.

The Origin of Langley Field

NACA appointed a subcommittee to investigate and report on the suitability of sites under consideration by the War Department. The Chief Signal Officer, Brig. Gen. George P. Scriven, officially invited NACA to join the Signal Corps' site search in a letter dated October 13, 1916. NACA's subcommittee produced a site report which noted that it "took advantage of examinations that already had been made under the direction of the Aviation Corps of the War Department, and thus narrowed the search very materially . . . the site most nearly meeting all required conditions was situated about 4 miles north of Hampton, Virginia, on the flat lands facing the two branches of Back River, which opens out into Chesapeake Bay."[11] NACA pursued assignment of a portion of the Army's new field for its aeronautical laboratory before the Secretary of War had approved the land purchase. Permission was granted by the Acting Secretary of War on December 27, 1916, but it did not identify a specific plot. The Army Chief of Staff and the Secretary of War approved the $290,000 purchase on December 15, 1916; the sale was finalized on December 30, 1916.

The Army's Aeronautical Experimental Station and Proving Ground was named Langley Field officially on August 7, 1917, although it had been known by this name as early as the fall of 1916. Langley Field was named in honor of Dr. Samuel Pierpont Langley, Secretary of the Smithsonian Institution (1887-1906), whom many at that time considered to be the true "father of aviation." The idea to name the field for Dr. Langley appears to have originated with Army air officers, either General Scriven or Colonel Squier, then chief of the Signal Corps Aviation Section.[12]

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[11]NACA site report, November 23, 1916.

[12]Colonel Squier was promoted to Brigadier General and Chief Signal Officer in early 1917.

The Great War

Development of military aviation in the United States was far behind that of Europe when war was declared in April 1917. War demands required a vast network of ground installations for training and for aircraft manufacturing, testing, and repair. Large appropriations were forthcoming; $10,800,000 for fiscal year 1918 (May 1917), and $43,450,000 as a deficiencies appropriation for 1918 (June 1917). The office of the Chief Signal Officer was in charge of planning the massive expansion of Army aviation; its $640 million program was approved in July 1917. The program emphasized planes and pilots, but the first need was obviously flying fields to accommodate them. When the United States entered the war, the Army Aviation Section had only three flying schools[13] and one experimental station, which was barely under construction. Four groups of fields were selected in phases, beginning in May-June 1917 and ending in early 1918. Three-year leases with options to purchase were the standard method of securing these fields. A basic airfield design was developed in May 1917 by Albert Kahn. It was based on a one-mile-square section with all buildings on one side.[14] An extensive program of temporary construction quickly rose around the country. In contrast, construction at Langley Field was slow because it was originally established as an experimental station and proving ground, with permanent, substantial buildings.

Overall, the results of these massive aviation efforts were limited, primarily because the networks required for real air power could not be developed in such a short time. Urgent wartime requirements and slow progress at Langley Field resulted in relocation of the experimental station to McCook Field in Dayton, Ohio. Congressional investigations eventually led to an Executive Order by President Wilson on May 20, 1918 for major reorganization. Army aviation was removed from the Signal Corps, and the Army Air Service was established as a combatant arm of the Army. Its two agencies included the Department of Military Aeronautics, responsible for training and operations of the air arm, and the Bureau of Aircraft Production, responsible for production of aircraft, aircraft engines and equipment. The Director of the Air Service coordinated the work of both agencies. The war was over before these training and production programs had much effect on the outcome of World War I.

The Post War Period

The Armistice on November 11, 1918, brought Army airfield construction work around the country to an immediate halt. Almost all airfields developed for the war effort were leased properties. Some were immediately abandoned, others were retained temporarily for demobilization as temporary storage depots. Large

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[13]Mauer Mauer, **Aviation in the U.S. Army, 1919-1939**, The United States Air Force General Histories (Washington, D.C.: Office of Air Force History, 1987), xxi.

[14]Brown, **Eagles Land**, 39.

sums of money expended on military aviation during the World War produced only temporary construction at a number of airfields--wood frame buildings and steel frame hangars. Langley Field and Rockwell Field, site of the Signal Corps Aviation School in San Diego, were the only stations that could claim any permanent construction at the end of the war,[15] and 90 percent of Rockwell's construction was temporary.[16]

The Chief of the Air Service developed a comprehensive airfield plan for operations and training in 1919, but the postwar period was one of instability and uncertainty for the Air Service. The Executive Order that established the Air Service in 1918 was formalized in June 1920 with an amendment to the National Defense Act. The Chief of the Air Service was to be a major general, an assistant chief a brigadier general, and authorized strength was 1,516 officers and 16,000 enlisted men. Air Service development, however, was repeatedly scaled back over the next several years. With America's retreat into isolationism came limited funding for national defense, continued reliance on seapower for the country's primary defense, and diminishing support for the young air arm as the importance of air power was debated.[17] Congress investigated the large wartime expenditures, and undertook a comprehensive review of all War Department real estate holdings. Air Service plans for its ground facilities were subject to great fluctuation in the postwar period, and the condition of buildings and flying fields deteriorated.

After the Armistice, NACA pursued official assignment of a location for its laboratory at Langley Field. The **Annual Report** for 1918 noted that Langley Field's original purpose "was to provide an experimental flying field and proving ground for aircraft. During the war the field was used primarily as a training school for aviators, but it is contemplated that after the war it will be fully developed in accordance with the original plan." The Aeronautical Experimental Station had been relocated to Ohio during the war, however, and early Air Service development plans included Langley Field as a fully operational air station with coastal defense responsibilities.[18]

By the time Dr. Walcott repeated NACA's request in Deccember 1918, the assignment of space on Langley Field for NACA's laboratory had become entwined

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[15]Brown, "Eagles Roost," 106.

[16]Ibid., 138, citing "Annual Report of the Chief of Air Service, 1925," 27.

[17]Ibid., 59.

[18]Mauer, **Aviation**, 109, citing Ernest L. Jones, "Chronology of Aviation, April 7, 1919 and May 19,1919," Ms, USAFHRC, Maxwell AFB, Alabama.

with the much broader question of the Army air arm's organization, and the disposition of its flying fields and depots acquired during the war. NACA's location on the flying field was also controversial for some Air Service officers. A number of serious issues were proposed for discussion, including transfer of ownership of all NACA buildings and improvements at Langley Field to the Air Service. An agreement was reached eventually on April 24, 1919. Acting Secretary of War Benedict Crowell approved a Memorandum from the Chief of the Air Service, Maj. Gen. Charles T. Menoher, recommending "that that portion of Langley Field known as Plot No. 16 be definitely set aside for use by the National Advisory Committee for Aeronautics for their purposes in constructing laboratories or other utilities necessary in scientific research and experiments in the problems of flight."

For the next two years, relations between Army and NACA personnel at Langley Field were quite strained. A number of issues were problemmatic during this period, but they all apparently originated from the same source; McCook Field had become the location of the Army's experimental station, and Langley Field had been turned over to general service. The Army Air Service's first comprehensive plan for airfield development in 1919 did not restore Langley Field's original experimental mission as NACA had expected. While the Army struggled with the plan for its flying fields and depots (1919-1922), relocation of NACA's laboratory was explored seriously because working and living conditions at Langley were so deficient. Army and NACA committees were appointed to identify a site and pursue legislation required for relocation. Numerous memos throughout the fall of 1919 concerned the need for relocation legislation, transferring NACA's laboratory to Bolling Field in Washington, D.C. Air Service development plans at that time called for "complete utilization of Langley Field, which will involve the removal from the field of all activities of the National Advisory Committee for Aeronautics."[19]

Brig. Gen. William (Billy) Mitchell, Assistant Chief of the Air Service, made special efforts to push the laboratory's relocation and get NACA off Langley Field. The animosity of some Air Service officers, particularly Mitchell, towards NACA's laboratory may have been provoked by NACA's promotion of civil aviation legislation, begun in 1918. "Throughout the battle for civil-aviation legislation, a shifting coalition of military and civilian believers would look to [Gen. Billy] Mitchell for leadership and identify--at least in their own minds--the fostering of civil aviation with reform of military aviation."[20] Establishment of a separate air force, which Mitchell's followers supported,

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[19]Memorandum for the Secretary of War, War Department, Air Service, October 10, 1919.

[20]Alex Roland, **Model Research: The National Advisory Committee for Aeronautics, 1915-1958** (Washington, D.C.: National Aeronautics and Space Administration, 1985), 59.

was condemned publicly by NACA. Dr. Walcott, NACA's chairman, believed it to be "a dangerous diversion from the main point, the need to establish in the Department of Commerce a bureau to regulate and encourage civil aviation."[21] "To the advocates of a separate or unified air service, you were either with them or against them," and this group saw NACA as "an obstacle to their designs."[22]

On June 11, 1920, NACA's laboratory was officially dedicated, in conjunction with completion of its first wind tunnel. The Air Service may have been concerned about NACA's entrenchment at Langley Field, but airmen presented a spectacular flying circus for the formal dedication, according to local accounts. NACA's laboratory was named the Langley Memorial Aeronautical Laboratory (LMAL), again in honor of Samuel Pierpont Langley. Rear Adm. David W. Taylor, Director of Naval Aviation and a noted naval architect and aircraft designer, made the keynote speech.

Relocation of the Army's aeronautical experimental laboratories at McCook Field in Dayton became necessary because the government lease on the property had expired. This relocation was debated for some time, and return of experimental activities to Langley Field was even promoted by some Air Service officers who saw Langley as their rightful home. The question of LMAL's relocation apparently resolved itself because relocation of McCook's experimental activities was not quickly decided, and conditions at Langley Field had greatly improved.

Army Aviation in the Early 1920s

After the Armistice, the interim organization authorized for the Air Service consisted of two wings, seven groups, and 27 squadrons, all of which were formed by the fall of 1919. Kelly Field was the headquarters for the 1st Wing and Langley Field was the headquarters of the 2d Wing. Due to the government's strict fiscal policy, the organization as of the spring of 1923 had been reduced to one wing, three groups, and 23 squadrons. Langley Field was the headquarters for the one remaining wing. Although the Air Service had been recognized since 1918 as a combatant arm of the Army, coordinate with the Infantry, Cavalry, and Artillery, this was not reflected in the organizational structure. It still reflected the air arm's original function as an auxiliary of the ground forces, not a separate striking force capable of independent operations. Eleven of the squadrons, or almost half, were observation squadrons, which were not used for offensive purposes. Air arm proponents believed that combat aviation should constitute 80 per cent of the strength (offensive air force versus defensive air service). In addition, all combat

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[21]Ibid.

[22]Ibid., 61 and 68.

aviation (pursuit, bombardment, and attack squadrons) was controlled by ground force commanders, not by the Chief of the Air Service.

Professional education for air officers during the 1910s was not comparable to that provided for officers of other arms and services.[23] Efforts to develop and standardize education and training began in October 1919 when the Chief of the Air Service requested authority to establish eleven special service schools for the Air Service. The schools authorized on February 25, 1920 included the Army Air Service School of Application at Langley Field, also known as the Air Service Field Officers' school. This school was the Army's first attempt to address the offensive and defensive aspects of military aviation, including the tactics, techniques, and employment of the air weapon.[24] It sought to establish a sound tactical doctrine throughout the Air Service, which eventually led to development of the Army's heavy bombardment air doctrine in the interwar years. In 1926, it was renamed the Air Corps Tactical School. The school was located at Langley Field from 1920 until 1931, when it relocated to Maxwell Field in Montgomery, Alabama.[25]

Brig. Gen. Billy Mitchell's service in World War I inspired him to become an outspoken advocate of the importance and effectiveness of air power, and the need for an air force co-equal to the Army and Navy. Mitchell wanted to prove that battleships were obsolete, but there were few examples of aerial attacks on ships. Shortly after his appointment as Assistant Chief of the Air Service, he proposed a test of airplanes against ships. The Naval Ordnance Tests were conducted in the summer of 1921, about 75 miles from the mouth of the Chesapeake Bay, and based out of Langley Field. Targets were three surrendered German vessels and an obsolete U.S. battleship. The event's importance was reflected in its list of distinguished attendees, including the Secretary of War, the Secretary of the Navy, the Army Chief of Staff (General Pershing), the Chief of the Air Service (General Menoher), senators, and representatives. The Naval Ordnance Tests reached a climactic point on July 20-21, when General Mitchell's 1st Provisional Air Brigade sunk the German battleship Ostfriesland. This historic event was also witnessed by a number of foreign observers and reporters.

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[23]Robert T. Finney, "Early Air Corps Training and Tactics," **Military Affairs** 20 (Summer, 1956): 155.

[24]Ibid., 155-156, 159-160.

[25]The Army flying school at College Park, Maryland (1911), which transferred to North Island, San Diego, California in 1912, taught technical aspects of flying and maintenance of aircraft. It did not teach the tactics of military aviation.

The Army Air Service concentrated on development of training during this period. Tactical units were responsible for aerial gunnery and bombing training, since there were no special schools for training of this type. Specific training efforts were initiated in the mid-1920s and continued into the 1930s. Annual bombing and gunnery matches were held from 1924 to 1932, and the Army air arm's best pilots, gunners, and bombardiers from units in the United States and the Panama Canal Zone participated in the competitions. To provide tactical training of units as an air force, the Chief of the Air Service obtained authority to concentrate pilots and airplanes at Langley and Mitchel Fields for maneuvers in October 1925. This successful exercise led to annual tactical maneuvers, with a different military problem explored each year. Tactical training to test mobility from 1923-1930 included cross-country flights of entire groups.

The Army Air Service was an early supporter of the development of civil aviation. An important contribution was the creation of a nationwide network of airways and landing fields to link key areas of the country, which served a military purpose as well. The Air Service initially undertook planning of air routes, location of stations, and mapping, and encouraged towns and cities to create and operate their own airports. An Airways Section was established in the Office of the Chief of the Air Service in September 1920. In February 1921, the Air Service established a model airway to serve as an example for the whole system. It linked Washington, D. C. and Dayton, Ohio. In 1922 the original airway was extended south from Washington to Langley Field and north to Mitchel Field, New York; from Dayton to Scott Field, Illinois; and from Moundsville, West Virginia (an intermediate stop between Washington and Dayton) to Selfridge Field, Michigan. Scheduled flights over the model airway began in 1922, hauling passengers and packages, and in 1923 it was extended again. The Air Service also developed and maintained communications, weather service, locations of emergency fields, and navigational markers as part of the system. Another advance for civil aviation was the first flight around the world. It was promoted by General Mitchell and planning for the flight began in 1923. Aviators worldwide had hopes of making this historic flight to develop civil aviation. Crews selected were Army Air Service flyers, and they received their training for the flight at Langley Field. Four airplanes took off from Seattle, Washington on April 6, 1924, and three completed the circumnavigation on September 28, 1924.

Lack of military appropriations during this period led to deplorable conditions for Air Service stations and buildings. World War I temporary buildings were built to last two to five years. With the exception of Langley Field, the Air Service had no prewar installations to fall back on, as did the Army. By 1925, efficiency, health, and morale had declined substantially throughout the Army. The Senate Committee on Military Affairs conducted hearings early in 1925 and reported as follows: "Since the end of the war, in the effort to carry out the government policy of strict economy, the buildings in which our Army is housed have suffered. Repairs have been limited to the barest necessity and very

little new construction has been done. In some of the largest and most important posts enlisted men and officers are living in temporary barracks constructed for war-time use on which makeshift repairs have been made and which are almost uninhabitable. The effect of such conditions on the health and morale of the Army is what might be expected. It has shown that in some places living conditions are intolerable."[26] In conjunction with these findings, Congress also recognized that Air Service strength was so deficient that it was not capable of handling an emergency. These conditions eventually produced a new law in 1926 to expand and strengthen Army aviation.

The National Advisory Committee for Aeronautics (NACA) and the Langley Memorial Aeronautical Laboratory (LMAL) in the 1920s

NACA's organic legislation had no clear goal. Committee efforts were initially channeled toward establishment of a national aeronautical laboratory. With that accomplished, NACA began development of an aeronautical research program for its laboratory to carry out. Research programs envisioned in September 1919 included "experiments on airplanes in full flight, model wind tunnel experiments (i.e., experiments in wind tunnels with models), development of instruments for navigation and operation of aircraft, and determining performance and stresses of planes in flight."[27] In the spring of 1920, Dr. Walcott wrote President Wilson that "the principal duty of the National Advisory Committee for Aeronautics is the conduct of scientific research in aeronautics . . . the continuous scientific study of the problems of flight."[28]

In this early period of American aeronautical development, "the history of design in aeronautics strikingly resemble[d] that in bridge engineering . . . [Bridges] were built by certain rules of thumb without any regard to or analysis of the stresses to which they would be subjected."[29] LMAL introduced methodical and scientific investigation of aeronautical design problems to place "the design of an airplane on the same scientific basis as that which has been employed for a long time in bridge design, where it is possible to know beforehand the stresses to which not only the entire structure but every one of its members will be subjected."[30] Unknown factors in airplane design were identified and qualitative means used to determine performance characteristics

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[26]Brown, **Eagles Land**, 65.

[27]Victory memo.

[28]Charles D. Walcott to President Woodrow Wilson.

[29]Making America Independent in the Air, **Mechanical Engineering**, September, 1923, Vol. 45, No. 9, 515.

[30]Ibid., 518-519.

of airplanes in flight.[31] The Langley Memorial Aeronautical Laboratory used empirical methods to solve aircraft design problems, and its tendency for experimental programs was in keeping with the state of American aeronautics in the 1915-1930 period.[32]

Wind tunnels were used to study aerodynamics as early as the 1830s. "A fundamental law of fluid dynamics is that a body immersed in a moving fluid experiences the same forces as if the body were moving and the fluid stationary, given that the relative speed of the fluid and the solid object is the same in both cases. This means that the conditions surrounding an airplane in flight can be replicated by holding the plane stationary and moving the air past it at a speed comparable to flight speeds."[33] Scientific methods and instruments make it possible to predict what forces an airplane in flight will probably encounter, based on tests of an airplane, or an accurate model of it, in a wind tunnel.[34] "Advantages of wind tunnels over flight testing are economy, safety, and research versatility. A model airplane can be tested in a wind tunnel at a fraction of the cost of building and operating a full-scale prototype, and the airworthiness of new and experimental designs can be tested without risking a pilot's life."[35] Flight conditions simulated in wind tunnels can be varied, measured, and more closely controlled than possible in flight research.

LMAL was in full operation by April 1921. By May 1921, operation of the laboratory was leading to a "decided change in the nature of the Committee's activities . . . Emphasis is now rapidly shifting and a constantly increasing portion of the time and money available is being devoted to the carrying on of research in the Committee's own labs," according to LMAL's chief physicist.[36] At that time, there were only 13 wind tunnels operating in the United States. These tunnels were occupied with routine testing of specific models, with "too little time to spare for real research." NACA's wind tunnel was "devoted

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[31]Charles D. Walcott, "Aeronautics in the Government-The National Advisory Committee," **National Aeronautic Association Review**, Vol. 3, No. 6, June 1925, 88.

[32]Hansen, **Engineer**, xxix.

[33]Roland, **Model Research**, 508.

[34]John F. Victory, "Foundations of Air Progress," **National Aeronautics**, January 1940, 8-9.

[35]Roland, **Model Research**, 508.

[36]Edward P. Warner, "Aeronautical Research in U.S.A.," **Aeronautics** 20 (May 19, 1921): 352-353.

entirely to the carrying out of a definite research programme without being constantly burdened with tests on the balance and efficiency of new designs of aeroplanes."[37]

NACA hired a scientist in 1921 to provide direction for its developing aeronautical research program. Dr. Max Munk, a German theoretical aerodynamicist from the Zeppelin Company, had abilities as a theoretician and generalist which the Committee expected would enable him to draw conclusions from LMAL's research; "the scientist providing the conceptual framework on which the NACA engineers would hang their researches."[38] LMAL's second wind tunnel was proposed and designed by Munk. Scale effect was a serious problem for wind tunnel research; it skewed research results and required correction to accurately simulate conditions encountered by an airplane in flight. Munk addressed scale effect with his Variable Density Tunnel (VDT), which could vary air density "so that almost any model of reasonable size could be tested under conditions comparable to those encountered by a full-scale aircraft in flight."[39] Munk did not discover the problem of scale effect, but he was the first to design a practical proposal based on the theory. The pressurized wind tunnel is "a technique that remains one of the NACA's greatest contributions to wind tunnel technology."[40] It began a worldwide revolution in aeronautical research. "It was the VDT, representing the Committee's first bold step in the direction of novel research equipment, which won the NACA its international reputation as a technologically outstanding research organization."[41]

The design of airplane wings was one of the most important research areas in this early period of aeronautical development. The VDT was the first tunnnel able to produce reliable measurements that could be used to develop a wing design based on scientific principles. Munk used the VDT to investigate a new airfoil theory he was developing, and this research produced a major breakthrough in airfoil design. The 1925 research report introduced NACA's first "family of wings."

In 1924, NACA Headquarters in Washington, D.C. gave up its six-year effort to find a scientist to direct NACA's aeronautical research. The Committee's executive officer, George Lewis (an engineer), assumed this position, with responsibility for NACA's technical direction. The head position at LMAL was

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[37]Ibid., 353.

[38]Roland, **Model Research**, 92.

[39]Ibid., 93.

[40]Ibid., 508.

[41]Hansen, **Engineer**, 99.

subsequently designated the engineer-in-charge. Lewis established a research process to refine "flight as it then existed . . . based on the belief that a smoothly running research organization holds the greatest promise of technological progress."[42] NACA's 1925 and 1926 annual reports reflected the basis for the research process envisioned by Lewis:

"There is nothing in sight at this time to indicate the probability of the discovery of a revolutionary principle contributing any great or sudden improvement in aircraft."[43] "It is apparent that the time has now arrived when the main theoretical foundation has been laid and we may expect in the future to find extensions of and additions to existing theory rather than new fundamental conceptions. We are therefore entering into a phase of refined and applied theory."[44]

Max Munk's volatile genius was not in sync with the new, orderly research process, and he resigned early in 1927. LMAL's research priority was aerodynamic principles basic to all aircraft, rather than testing for specific aircraft design problems. "The research process . . . worked exceedingly well . . . The system may have lacked brilliance and inspiration, but it provided a rational and defensible system of research selection."[45]

There are differing opinions about the route NACA chose for its research in the mid 1920s, which was followed for the next 20 years:

> "For better or for worse, the NACA by 1926 was committed to a research philosophy that valued process over prescience, the team over the individual, experiment over theory, engineering over science, incremental refinement of the existing paradigm over revolutionary creation of new paradigms."[46]

Many LMAL veterans, however, have a different point of view:

> "In the early '20s no one knew for sure what the right problems for research were for an agency like NACA . . . By 1926, experience was beginning to show that many of the most urgent problems in that period involved engineering questions like 'is it worthwhile to

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[42]Roland, **Model Research**, 97.

[43]Annual Report, 1925.

[44]Annual Report, 1926.

[45]Roland, **Model Research**, 106.

[46]Ibid., 97-98.

> retract landing gears,' or 'can I reduce engine drag without degrading cooling'--questions which NACA could answer with the aid of large new facilities, affordable only by the government.
>
> Dr. Ames fostered and approved such work because it was urgently needed--not because NACA had decided to reject science or theory. As a Ph.D. in physics, Ames understood scientific research at least as well as Munk. Lewis also had a stronger than usual academic background. There was no rejection of individual research, or theory, or fresh ideas."[47]

The formative years for NACA and LMAL were over by the mid 1920s. At the end of World War I, there were two prevailing areas for aeronautical research; the aerodynamics of the airplane and powerplants (as engines were then called). "NACA settled upon aerodynamics as its main field of interest . . . an area of specialization . . . offering real opportunity to advance aeronautical science."[48] NACA's real mission, aeronautical research, became clear during this developmental period, as did the role of the National Advisory Committee for Aeronautics. NACA had become a research agency rather than an advisory committee. NACA Headquarters in Washington, D.C. ran the show, securing funds and making sure the program satisfied NACA's customers, primarily the military services and the aircraft industry, but "the aeronautical research to which the NACA was dedicated was conducted at Langley" [Field.][49] The death of Charles Walcott in 1927, NACA's chairman since 1917, also marked the end of this early phase.[50]

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[47]Ibid., 346, Footnote 65, quoting John V. Becker, NACA veteran.

[48]Ibid., 88-89.

[49]Ibid., 101.

[50]Walcott's "genius had been political and organizational, consummating in the give and take of Washington politics the dream of establishing for the United States an aeronautical research organization rivaling those of Europe. He, more than any other individual, had guided the campaign through the frustrating years of failed commissions and stalled legislation, and had ensured for the nascent committee an acceptable status within the government hierarchy and the American aviation scene. Although he never mastered the technology of aviation, as a bureau-builder he was without peer." Ibid., 100.

The late 1920s was a boom period for aviation in America. The place of civil aviation in the Federal government was resolved in 1926 with the Air Commerce Act. Federal support of aviation was also demonstrated by the Army Air Corps Act of 1926, accompanied by aircraft building programs to provide strong aviation arms for the Army and the Navy. Charles Lindbergh's 1927 transatlantic flight from New York to Paris further contributed to a growing national awareness and support of aviation. The aircraft industry experienced substantial growth due to the expansion of civil and military aviation.

NACA had always recognized the importance of commercial aviation, even stating in 1927 that "civil aviation must in itself be regarded as one of the most important factors of civilization."[51] NACA was also an important player in the long debate (1918-1926) over the place of civil aviation in the Federal government. LMAL research efforts focused on military requirements in the early 1920s, but growth of commercial aviation changed the direction of LMAL research. In 1926 NACA initiated an annual aircraft engineering conference to provide the aircraft industry better access to NACA and LMAL.[52] Aviation leaders from government, educational institutions that taught aeronautical engineering, and representatives of aeronautical trade journals were also invited. NACA adapted its research priority (for long-range fundamental investigations applicable to all flight) to permit conference requests for short-term practical research.

NACA's building program of the late 1920s illustrated a trend, as well as "daring and originality" in development of research equipment for the Langley Laboratory.[53] With the VDT, "NACA became famous for innovative research techniques and tools, and used this fame to win more funds from Congress for equally innovative facilities and equipment in the years to come."[54] NACA's director, George Lewis, requested $33,000 in the FY 1927 budget to initiate construction of LMAL's third wind tunnel, the Propeller Research Tunnel, for testing of propellers at full scale. In May 1927, NACA received a research request at its second annual aircraft engineering conference for an aircraft engine cowling. The request was seen as an opportunity to address industry needs and to explore research applicable to all aviation. The Propeller Research Tunnel (PRT) had just been completed, and it was the perfect facility for the cowling investigation. The PRT had a 20-foot throat (test section),

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[51]Ibid., 109.

[52]Industry representatives had never been permitted as members on NACA's principal committees, only on technical subcommittees, because of potential conflicts of interest.

[53]Roland, **Model Research**, 106.

[54]Ibid., 93.

where propeller experiments could be conducted at full-scale, and it was the largest wind tunnel in the world.

Within months, LMAL researchers developed a cowling that enclosed the exposed fins of air-cooled engines. In February 1929, a Lockheed Air Express flying from Los Angeles to New York established a new nonstop record of 18 hours and 13 minutes; with the NACA cowling, its top speed was increased from 157 to 177 miles per hour. Fuel cost savings and operating cost reductions resulted, expanding the market for airplane purchases and operations. NACA and LMAL received their first Collier Trophy in 1929 for development of the aircraft engine cowling.[55] Manufacturers around the world adopted the NACA cowling almost universally in the 1930s and later, making it one of the most significant aeronautical advances of the 1920s.[56]

The next tunnel proposed by NACA was a full-scale wind tunnel, and funds for its construction were included in the FY 1928 budget. It was to be even larger than the PRT, from a 20-foot test section to a 30- by 60-foot throat. The initial request for funding was not approved. In the meantime, the importance of NACA's cowling had been demonstrated, and this accomplishment was exploited with the Bureau of Budget and the Congress. NACA emphasized that superior equipment had produced superior results, "that the research facilities of the Committee had helped determine the quality of the product."[57] The 1928 Annual Report noted that "this single contribution will repay the cost of the propeller research tunnel many times and fully justifies the committee . . . in recommending that additional funds be provided next year for construction of a full-scale wind tunnel."[58] Because of the cowling, a full-scale tunnel was subsequently authorized, even at a cost of $ 1 million. "With NACA's reputation and boldness growing, the Committee was now trying to secure its newly won position as the best equipped and most productive aeronautical research establishment in the world."[59]

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[55]The Collier Trophy is the nation's highest aeronautical award, presented annually "for the greatest achievement in aviation in America, the value of which has been thoroughly demonstrated during the preceeding year."

[56]Roland, **Model Research**, 116.

[57]Ibid., 117.

[58]1928 Annual Report, p.80.

[59]Roland, **Model Research**, 108.

Army Aviation in the Late 1920s and Early 1930s
The Air Corps Act of 1926 was enacted to expand and strengthen the Army air arm. The name change emphasized Army aviation's new tactical status as an air force with potential striking power. An Assistant Secretary of War for Air was authorized, and Army aviation was represented on the War Department General Staff for the first time. The Act authorized an expansion program to be accomplished over five years (1927-1932), but it did not include appropriations for the expansion. Funding was to come from annual or supplemental appropriations. The Army Housing Program was also authorized in 1926, providing funds for permanent housing at Army posts to upgrade temporary, dilapidated WWI facilities that had become a national disgrace. In the early years of the expansion program, Army housing construction and the expansion program's technical construction were treated separately by Congress. By 1928, both types of construction were considered jointly.[60]

The Five-Year Program included two new wings for the Air Corps' Air Combat Forces--another bombardment wing, the 1st Bombardment Wing with headquarters at March Field, California; and an attack wing, the 3rd Attack Wing with headquarters at Fort Crockett, Texas (pending completion of Barksdale Field, Louisiana). The 2d Bombardment Wing headquarters had been at Langley Field, Virginia since the early 1920s. Twenty more squadrons were authorized (up to 52), with all new units to consist of combat aviation. Authorized personnel increased from 919 officers and 8,725 enlisted men to 1,650 officers and 15,000 enlisted men. The number of airplanes was to rise from 1,254 to 1,800. This was a progression from Army aviation's previous function as an auxiliary for other Army units, but not the independent air arm promoted by many.

The Office of the Chief of the Air Corps developed a comprehensive plan for the expansion program by the spring of 1927. The Air Corps Act had not specified new ground facilities, but personnel and equipment increases necessitated construction at Air Corps stations for housing, training, and support of the new units authorized by the law. This was the first permanent construction program for the Army air arm, and significant improvements were made at almost all 32 existing stations and depots that had been retained after World War I. The development plan also called for establishment of two new fields. One of these was to be an Air Corps training center to consolidate all flying training, which eventually became Randolph Field in San Antonio, Texas. The Air Corps expansion program and the Army Housing Program provided American cities and towns their first real commitment to permanent occupation by Army aviation. The earliest permanent construction at all historic Army aviation stations is

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[60]Brown, **Eagles Land**, 75.

associated with these programs, with the exception of Langley and Rockwell Fields.[61]

Overall, the Five-Year Program was considered a failure because actual appropriations did not permit expansion to be carried out as authorized. It ended in 1932, when a number of uncompleted projects were cancelled or postponed by Congress because of the Great Depression. Relief appropriations were subsequently used, however, to carry out cancelled or postponed projects, and previously unemployed relief workers provided labor for Air Corps construction projects.[62] In spite of the "failure" of the expansion program, Air Corps stations were dramatically transformed with well-designed, substantial, permanent buildings and infrastructure during this period.

In contrast to the massive construction program, Army Air Corps operations and training suffered from lack of appropriations for these purposes during the early years of the Depression. The annual bombing and gunnery matches, as well as Air Corps annual maneuvers, were cancelled. Most Air Corps activities in the early 1930s were of a civil nature (disaster relief, rescues, forest fire patrols, etc.) Establishment of the Civilian Conservation Corps (CCC) also impaired Air Corps operations. CCC workers were housed at Army posts and trained under Air Corps supervision, requiring a large number of Air Corps officers for CCC duty.

The Army Air Corps was ordered to carry the United States mail on February 9, 1934, after airline contracts for mail delivery were cancelled due to fraud. This was "one of the largest projects, and in many ways the most important undertaken by the Army's air arm in the interwar years."[63] The Air Corps had one week to rework its airplanes, which were not equipped for all-weather flying. The Air Corps' inadequate equipment and ground organization led to a number of serious accidents in the next few months, many fatal. Congressional investigations of the Air Corps followed, including that of the Baker Board. Gen. Benjamin Foulois, Chief of the Air Corps, considered the Baker Board's investigation report to be "the first comprehensive outline of War Department policy with respect to aviation that the Army has ever had."[64] As the result of the air mail fiasco, another reorganization of Army aviation followed, eventually providing "more equipment, more personnel, greater recognition of

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[61]Jurisdiction of Rockwell Field was transferred from the Army to the Navy in 1935.

[62]Brown, "Eagles Roost," 159 and 191.

[63]Mauer, **Aviation**, 299.

[64]Ibid., 317, citing Memo, Westover for Plans Division, July 23, 1934, USAFHRC, Maxwell AFB, Alabama.

its basic mission, and more freedom of action."[65] General Headquarters Air Force (GHQ Air Force) was established with a commanding general in charge of all tactical air units (i.e., combat aviation) for the first time. This was not the separate air force long sought by airmen, but it was the first real step toward creation of an autonomous air arm within the Army.

GHQ Air Force was established March 1, 1935. The Air Corps' three wings of air combat forces and an airship group were under its command. GHQ Air Force headquarters (HQ GHQ Air Force) was based at Langley Field, which was also the headquarters of the 2d Wing (1st Bombardment Wing--March Field, California, 3d Attack Wing--Barksdale Field, Louisiana). GHQ Air Force also had jurisdiction over three other stations (Mitchel, Selfridge, and Hamilton Fields), providing six permanent stations for its four bombardment, three pursuit, and two attack groups. These nine groups included 10 bombardment, nine pursuit, six attack, and four observation squadrons. Although GHQ Air Force controlled all combat aviation, the Chief of the Air Corps retained responsibility for personnel, supply, training, and schools, and Army corps area commanders still controlled the stations with GHQ Air Force units.

Brig. Gen. Frank M. Andrews "was assigned the most important air command in the Army,"[66] with primary responsibility for determining how to organize and train a highly mobile air force. GHQ Air Force's first year was a service test of the new organization's capabilities. Exercises and maneuvers were planned to test mobility and provide experience in field operations. In December 1935, the first exercise involving all three wings was conducted in Florida by HQ GHQ Air Force. This was the largest, most important operation of the year, and its major purpose was the development and testing of communication methods and procedures.[67] The exercise demonstrated GHQ Air Force's inability to control its personnel and equipment, due to the division of authority and overlapping jurisdictions with the Chief of the Air Corps and Army corps area commanders.[68] It also revealed an extreme shortage of trained communications personnel and an "almost total absence of field radio equipment" for the exercise. General Andrews subsequently reported to the Army Chief of Staff: "There are not

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[65]Edwin L. Williams, Jr., "Legislative History of the Air Arm," **Military Affairs 20** (Summer, 1956):88.

[66]DeWitt S. Copp, **A Few Great Captains: The Men and Events That Shaped the Development of American Air Power** (Garden City, New York: Doubleday and Co., 1980), 292.

[67]Mauer, **Aviation**, 336.

[68]Ibid., 333

sufficient commissioned personnel in GHQ Air Force for active operations against an enemy."[69] The service test led to further reorganization in 1936.[70]

While GHQ Air Force was given time to prove itself, Army airmen shifted their advocacy for a separate air arm to the doctrine of strategic bombardment, which had been under development at the Air Corps Tactical School since the early 1920s. The Air Corps promoted development of a long-range heavy bomber. The new bomber was seen as the way to implement strategic bombardment doctrine, emphasizing Army aviation's role as a separate striking force, rather than an auxiliary. A design competition in 1934 produced the prototype of the Boeing B-17 (Flying Fortress), a four-engine bomber of revolutionary design. It successfully completed its first flight test in July 1935. The War Department authorized purchase of 13 B-17s, which were delivered to the Air Corps in 1937.

NACA and LMAL in the 1930s

NACA's general purpose budget declined for the first time in 1933 and 1934 because of the Great Depression. Construction funds were not appropriated through the usual channels from 1931 through 1937. During this period, however, NACA received approximately $674,000 for construction from the Public Works Administration, in the name of economic recovery. As the Depression deepened, NACA did not maintain its late 1920s commitment to commercial aviation, especially after the aircraft industry was charged with profiteering and corruption. NACA developed a policy for private industry research in 1931, with an accompanying table of fees. It permitted specific requests from American sources for research that could only be conducted at LMAL, because the laboratory had the VDT and the PRT, the only such facilities in the country.[71]

In 1933, NACA published **Characteristics of 78 Related Airfoil Sections from Tests in the Variable-Density Tunnel**. LMAL had continued Max Munk's VDT program to develop improved airfoils. Its report of that research "introduced what was to be the VDT's principal achievement as an aeronautical research tool: a second and more significant series of airfoils, the NACA 4-digit series . . . From that catalog, the American aircraft industry picked NACA airfoils that became the wings for some of the best aircraft of their era, including the DC-3 transport and the B-17 Flying Fortress, as well as a number of postwar general

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[69]Copp, **Great Captains**, 292.

[70]GHQ Air Force headquarters remained at Langley Field until March 1941, when war preparations required its transfer to Bolling Field, Washington, D.C.

[71]Prior procedure had been to refuse such investigations because of the policy to conduct fundamental research applicable to all flight.

aviation aircraft."[72] The 1933 report also introduced a new numbering system developed by LMAL for airfoil families which designated airfoils with four numbers. The number code identified an airfoil section's critical geometrical features in a specific sequence, enabling engineer's to visualize the airfoil's physical shape.[73] This system subsequently became the standard for designating series of airfoils, and wings became known by the Committee's name, followed by a number code. The NACA 0230 family of wings, the "two-thirty family," was the most famous of the 4-digit series, introduced in 1935.[74]

Early aeronautical research (in the 1920s) dramatically improved aerodynamic designs for engine cowlings, propellers, and wings in a short period of time. But, "as they delved deeper into the problems of the airplane, Langley engineers found that more sensitive, more powerful, more specialized laboratory equipment was needed--research tools that would get results more closely approximating those measured in actual flight . . . They found the old tools of research crude, inadequate, and in some cases misleading. So they proceeded to improve the old tools and to invent new ones."[75] Scale measurements were required to achieve accurate research results because all wind tunnel research utilized models or specific parts of airplanes, with the exception of full-scale studies. There are three ways to make scale measurements of lift, drag, and other airflow effects approach those of actual flight. These three methods led to three broad lines of wind tunnel development: large scale, high speed, and low turbulence.[76]

The first development in wind tunnel design was the trend to large, or full-scale, research, which utilized larger test objects or actual parts of the

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[72]Hansen, **Engineer**, 97-99.

[73]airfoils were previously numbered in the sequence in which they were tested.

[74]Roland, **Model Research**, 540.

[75]George W. Gray, **Frontiers of Flight: The Story of NACA Research** (New York: Alfred A. Knopf, 1948), 34.

[76] "It is a principle of physics that the responses of an object to airflow depend on its size, the speed with which it (or the air) is moving, the density of the air, and the viscosity (or stickiness) of the air. The multiple of the first three factors divided by the fourth, viscosity, provides a scale index known as the Reynold's number . . . You can increase the Reynold's number of an object by increasing its size, or by increasing its speed, or by increasing the density or decreasing the viscosity of the medium in which it operates." Ibid., 35

airplane, rather than small models. Testing at full-scale reduced scale effect to a negligible amount. The Propeller Research Tunnel, where full-scale propeller installations were tested, and the Full Scale Tunnel, which could accommodate whole airplanes, represent this line of wind tunnel development.

The second line of wind tunnel development was the trend to high-speed research. Testing at higher air speeds increases an object's Reynold's number, making results more comparable to flight conditions. LMAL began to plan its first high-speed wind tunnel in 1927 shortly after Dr. Joseph S. Ames, a strong proponent of high-speed research, became chairman of NACA's Main Committee. Attention was not focused on the speed factor initially because high-speed tunnels require massive tunnel structures and expensive power installations, and they also have operating complications. Development of high-speed aircraft, however, required high-speed testing to obtain high Reynold's numbers, and later to obtain high MACH numbers. A large high-speed tunnel became an urgent need, large enough for sizable models of complete airplanes and capable of continuous operation at hundreds of miles per hour. The 8-Foot High-Speed Tunnel (8-Foot HST) was authorized by the PWA in July 1933 and placed in service in March 1936. It was the "world's first high-speed tunnel of large size" with an 8,000 horse-power motor, designed to reach a speed of 500 miles per hour. "The eight-foot tunnel is a landmark in the history of tunnel design. It represents in the high-speed field a position comparable to that which the propeller research tunnel occupies in the full-scale field."[77]

The third line of wind tunnel development was the trend to low turbulence. The third way that scale measurements can be made comparable to those of actual flight is by increasing air density, as was done in the VDT. LMAL researchers gradually became aware, however, that the VDT had a great amount of turbulence. Authorization of a new, larger VDT, a low-turbulence tunnel, required an extended effort by NACA. The difficulty of communicating the need for such a tunnel to lawmakers uneducated in aeronautical science, coupled with political funding considerations, made this a hard sell for NACA. The request for Jacobs' low-turbulence tunnel was initially rejected, in part due to plans for a super PRT. The new tunnel proposed for high-speed propeller research was the 19-Foot Pressure Tunnel. It was to be large enough to test complete airplane models that incorporated minor construction details, thereby reducing scale effect to a negligible amount. Industry had been demanding such testing, and political considerations made it easier to justify a super PRT than a low-turbulence tunnel. An icing tunnel received authorization in May 1937 because of numerous crashes attributed to icing. Commercial airlines urgently needed information, which made funding for an ice tunnel politically expedient. The ice tunnel's stated purpose was carried out with a series of experiments in the summer of 1938. It was immediately converted to a low-turbulence pressure tunnel to study low-drag airfoils.

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[77]Ibid., 43.

The new tunnel was used to explore a new airfoil concept developed by Eastman Jacobs and his VDT section during NACA's search for funding for the tunnel. Their work produced a significant aeronautical development, which was publicly announced for the first time in the 1939 Annual Report: "Discovery during the past year of a new principle in airplane-wing design may prove to be of great importance. The transition from laminar (smooth) to turbulent flow over a wing was so delayed as to reduce the profile drag, or basic air resistance, by approximately two-thirds. It is too early to appraise adequately the significance of this achievement. So far, its application is limited to small airplanes, but there are indications of its ultimate applicability to larger airplanes through continued research. It should increase the range and greatly improve the economy of airplane operation."

North American Aviation's P-51 Mustang was the first airplane to utilize LMAL's laminar-flow airfoil. Its low-drag wings, "the result of years of NACA research on wing characteristics, became a hallmark of NACA achievement . . . John Victory [NACA secretary/executive secretary, 1915-1958] was pleased to report in later years that captured German documents revealed an inability by the Germans to account for the superior performance of the Mustang, even after they captured one intact and tested it, because their wind tunnels could not duplicate the low turbulence produced by NACA."[78] "Low-drag wings are high-speed wings . . . NACA experimenters were able to develop wings with this "critical" (element of) speed fifty miles per hour higher than that of the best conventional wings."[79] "The delineation of . . . laminar-flow airfoils was thus a great contribution by Langley . . . Wing sections developed by NACA at Langley became by far the most widely used sections worldwide."[80]

NACA, LMAL and World War II

By 1935, the Depression was over for NACA, but valuable time had been lost "in the international race for aeronautical supremacy . . . NACA still claimed in mid-1935 to be the leading aeronautical research laboratory in the world, but that claim would soon be challenged."[81] In March 1936, NACA's "intelligence officer," established in Paris in the late 1910s to gather information on European aeronautical developments, reported great expansion of aeronautical research in Germany, England, France, and Italy. "The Germans, traditionally strong in applying the science of aerodynamics, were in the midst of what appeared to be a major revitalization of their country's aeronautical resources. As a result of Nazi support, there would soon be five major regional

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[78]Roland, **Model Research**, 195.

[79]Gray, **Frontiers**, 110.

[80]Hansen, **Engineer**, 117-118.

[81]Roland, **Model Research**, 146.

stations for aeronautical research and development in Germany."[82] In response to these warnings, NACA formed a Special Committee on Aeronautical Research Facilities in March 1936, which produced a deficiency appropriation for 1936 and an increased budget for 1938. From 1935 on, NACA Annual Reports and American aeronautical journals warned of greatly accelerated European aeronautical research. Neither the Congress or the Bureau of the Budget recognized "that a crisis was in the making, a crisis requiring a crash program in aeronautical research."[83]

In September 1936, George Lewis traveled to Europe specifically to investigate aeronautical research in Germany and Russia, touring "the vast facilities initiated or expanded under Hitler and . . . [noting] the unparalleled German commitment to aeronautical supremacy."[84] He was particularly concerned about the large number of German personnel; 1,600-2,000 at one laboratory alone compared to Langley's 350. The German engineers also had special training, especially in comparison with the Langley practice of employing recent engineering graduates for on-the-job training.[85] In response to Lewis' trip report, NACA formed another special committee in October 1936, the Special Committee on Relation of the National Advisory Committee on Aeronautics to National Defense in Time of War. This committee was "unable or unwilling to formulate any recommendations until the summer of 1938."[86] The Special Committee's report was finally issued in August 1938. It recommended establishment of a new aeronautical laboratory to relieve "the congested bottleneck of Langley Field . . . and to disperse the Committee's research facilities so they would not be vulnerable to a single attack."[87] Another committee recommendation was that NACA become an arm of the military services during wartime through the Aeronautical Board, a joint Army-Navy board that coordinated all military aeronautics. The Special Committee's recommendations were incorporated into the Aeronautical Board's mobilization plan, including an exemption for NACA personnel from military service in the event of war. President Roosevelt approved the Aeronautical Board's mobilization plan on June 29, 1939.

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[82]Hansen, **Engineer**, 188.

[83]Roland, **Model Research**, 147.

[84]Ibid., 147.

[85]Ibid., 149.

[86]Ibid.

[87]Ibid., 154.

In October 1938, NACA appointed a Committee on Future Research Facilities. Its recommendation for expansion of LMAL, establishment of a new laboratory in Sunnyvale, California, and construction of facilities for specific research on military airplanes, was authorized in August 1939, an unprecedented expansion of the Federal government's aeronautical facilities. A California location was selected for the Federal government's new aeronautical laboratory, primarily due to the growing west coast aircraft industry. Construction began at Moffett Field (approximately 100 acres) in 1940, then occupied by the Army Air Corps. By the fall of 1940, a substantial part of the research staff necessary to operate the new facilities had been assigned and relocated from LMAL. The Ames Aeronautical Laboratory was named to honor Dr. Joseph S. Ames, chairman of NACA's Executive Committee 1920-1937, and NACA Chairman 1927-1939. On June 26, 1940, a third major research laboratory, for aircraft engine research, was authorized. A site was selected in October 1940 near the municipal airport in Cleveland, Ohio, where research began in June 1942.[88]

NACA personnel summary as of January 1941:

Washington office	76	Aircraft Engine Research Lab (expected)	300
Langley Field	848		
Moffett Field	130		
	1,054 [89]		

In preparing for war, the Federal government's only aeronautical laboratory for more than 20 years became the "mother" lab, providing key personnel for the two new laboratories. Langley and Ames were aeronautical laboratories; Cleveland specialized in engine development (an area primarily addressed by industry before this time). "NACA's most important preparation for the impending war was its construction of two new research laboratories. These projects consumed vast amounts of time and material, distracted and in some cases completely occupied key members of the staffs at both headquarters and the Langley laboratory, and led to a radical change in the way the NACA operated."[90]

In addition to efforts to establish the new laboratories in California and Ohio, the priorities of the coming war also directed LMAL's research program well before Pearl Harbor. Both military and commercial aviation benefitted from

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[88]The Cleveland laboratory was named the Lewis Flight Propulsion Laboratory after the death of George Lewis in 1948.

[89]John Victory, Outline for Groundbreaking, January 1941.

[90]Roland, **Model Research**, 173.

aerodynamic design improvements in the 1920s and early 1930s. These initial developments enabled aircraft designs to be specialized, and resulted in diverging design requirements for military and commercial airplanes in the mid 1930s. The military required higher speeds and altitudes, while the priorities of commercial aviation were safety and efficient operation. In anticipation of U.S. involvement in World War II, the focus of NACA's research program was strictly military. The last of the annual laboratory meetings was held in May 1939. Its military title, "14th Annual Inspection of the N.A.C.A. Laboratories," reflected the changed agenda.

NACA was placed on a war footing with President Roosevelt's approval of the Aeronautical Board's mobilization plan in June 1939. NACA "did everything it could to meet the requests of the services and to defer its own programs in the interest of national security."[91] For the duration of the war, LMAL essentially became an aeronautical engineering and research facility for the armed services. NACA's Technical Report and Technical Note, major publications which previously received wide distribution, were "virtually suspended . . . replaced by a series of wartime reports, all classified and with limited distribution, usually within the military services and among industry contractors having a need to know."[92]

NACA's LMAL conducted a wartime program of unprecedented proportions to refine (cleanup) military aircraft, primarily with its drag cleanup test. The test identified specific airplane design flaws resulting from faulty design or manufacturing process defects. Specific aerodynamic design improvements reduced drag and increased top speed, achieving dramatic improvements in performance for Army and Navy prototypes prior to production. The Brewster XF2A-1 Buffalo, an experimental Navy fighter, was the first prototype subjected to LMAL's drag cleanup test. Its top speed was increased by 31 miles per hour to 281, greater than ten percent. Subsequently, the Army and Navy sent all their prototypes to LMAL for drag cleanup. The program continued throughout the war, and was primarily carried out in the Full-Scale Tunnel. "Here again . . . NACA engineers were demonstrating how the correct design of small details improved the performance of an aircraft. The significance of this work should not be underestimated: by pointing out ways for these aircraft to gain a few extra miles per hour, the NACA effort might often have made the difference between Allied victory and defeat in the air."[93]

Army Aviation and World War II

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[91]Ibid., 177.

[92]RIbid., 179.

[93]Hansen, **Engineer**, 202.

The mission of GHQ Air Force's combat aviation was to defend the United States from land or sea attack, but defense requirements were secondary to political considerations in the interwar years. The Army air arm was never strong enough to carry out its defense responsibilities during this period. The military strategy resulting from the country's isolationism and insufficient military expenditures necessitated massive and rapid expansion with the threat of war. Army aviation ground installations could not accommodate massive personnel and equipment increases, and they lacked the technology and engineering developments that had accompanied advances in airplane design and performance. An unprecedented expansion of the Army Air Corps was initiated in 1939. The first law enacted for military preparedness was in April 1939, which authorized 3,204 officers, 45,000 enlisted men, and 6,000 planes for the Air Corps. Between September 1939 (invasion of Poland) and December 1941 (Pearl Harbor), the goal for Army aviation combat groups went from 24 to 41 to 54 to 84. The goal for trained pilots in 1941 was 30,000, up from 300 in 1938. Congress appropriated $2.5 billion for the Air Corps in fiscal year 1941, exceeding the total for all military aviation since 1909.

Continuing attempts to address the air arm's divided command led to another reorganization in June 1941. The Army Air Forces was created to coordinate activities of the Office of the Chief of the Air Corps, the Air Force Combat Command (GHQ Air Force's successor), and some minor units. The Chief of the Air Corps and the Commanding General, Air Force Combat Command, had service and combat responsibilities respectively, and were under the jurisdiction of the Chief of the Army Air Forces. The air arm achieved greater autonomy with this reorganization, but the division of service and combat duties continued to be a problem. There was a reluctance to undertake further large-scale organizational changes because of interference with the expansion program, but another reorganization was being planned when Pearl Harbor was attacked.

The organizational structure of GHQ Air Force became the prototype of the Army's numbered air forces in World War II. Significant changes were required due to their size and diversity, resulting in subordinate commands for bombardment, fighter, air defense, troop carrier, and tactical operations. The division of air force functions along strategic (bombardment) and tactical (combat) lines led to separate air forces for strategic and tactical operations.

HISTORY OF LANGLEY FIELD

Origin of the Flying Field

In August 1916, Congress appropriated $300,000 for the purchase of a flying field for the Army. For several years, the Army Signal Corps had been gathering information on conditions and sites suitable for flying, which enabled development of general criteria for its proposed aeronautical experimental station and proving ground: 1,600-1,800 acres (two miles by one mile, with the long axis into the prevailing wind), east of the Mississippi River, south of the Mason-Dixon line, within 15 hours of New York City, and not so close to unprotected coasts as to be vulnerable to attack. Specific requirements for the site included climate, proximity to industry, character of land for experimental flying, facilities for over-water flying, market for employing mechanics, cost of living, etc.[94]

The prospect of a large government project prompted residents of Hampton, Virginia to pursue location of the new flying field in their area. Hunter R. Booker, Nelson S. Groome, and Harry H. Holt formed a committee that assembled 1,659.4 acres (2 1/2 miles long by 1 1/4 miles wide) on the Back River, and offered it to the Federal government. The offer included construction of an electric railroad connecting Hampton and the new government land, and a bridge over Back River wide enough for automobile traffic. Water was to be furnished by the Newport News Light and Water Company.

During this same period, the National Advisory Committee for Aeronautics (NACA) was seeking a site for its first aeronautical laboratory. On October 9, 1916, NACA appointed a subcommittee to investigate and report on the suitability of sites under consideration by the War Department. This was followed by an "overture" from Dr. Charles D. Walcott, chairman of NACA's executive committee, to the Chief Signal Officer, Brig. Gen. George P. Scriven, who officially invited NACA to join the search for a site on October 13, 1916. Army, Navy, and NACA representatives visited the Hampton, Virginia site on November 18, 1916.[95] NACA's subcommittee prepared a report (dated November 21,1916) that recommended the Hampton location to the Army board of officers appointed to inspect sites. Prior to the purchase of the property, NACA's secretary, John Victory, was "instructed to request permission for National Advisory Committee for Aeronautics to use certain portions of the proposed proving ground now being

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[94]Brown, **Eagles Land**, 28.

[95] Numerous accounts of Langley Field's origin include the Navy as a main partner. Although the Navy participated in several site discussion meetings and a site visit on November 18, 1916, the Navy had no real interest in the Army's proposed experimental station at this time.

acquired,"[96] which was done in a letter dated December 12, 1916. In response, NACA was granted such permission by Acting Secretary of War Ingraham on December 27.[97] The sale of the property was finalized on December 30, 1916. It included all or parts of six plantations, with Sherwood Plantation's 720 acres comprising the bulk of the new government land.

On February 13, 1917, NACA requested assignment of specific space on the new aviation field, "near the water front and preferably near the western end of the field." Brig. Gen. George O. Squier, Chief Signal Officer, responded on March 1, 1917 that "it will be agreeable and convenient to this Office to assign such space but not until the work of preparing Langley Field is in a more advanced state."

Although General Squier referred to the new proving ground as Langley Field at that time, the field was not officially named until August 7, 1917. The Langley Field name apppears to have originated with Army air officers, and was in common usage long before its official designation. An October 13, 1916 letter from General Scriven to Dr. Walcott includes the suggestion that the planned field be named in honor of Samuel P. Langley.[98] An early aeronautical journal, **Aviation**, reported in its December 15, 1916 issue that Colonel Squier publicly stated his intention to name the new experimental station Langley Field as a "monument to the memory of Professor Langley."[99] During its first year, 1917,

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[96]"Important Events in Early History of National Advisory Committee for Aeronautics," 3.

[97]Ibid.

[98]Hansen, **Engineer**, 11.

[99] This occurred on November 28, 1916 in New York, at a banquet in Squier's honor by the Aeronautical Society of America. Dr. Langley was one of the first Americans to try and build a flying machine equipped with a motor. His work was supported by the Federal government with its first appropriation ever made for aviation purposes. Langley received $50,000 which he used to design and construct a large flying machine, Aerodrome A. It was to be launched by catapult mounted on a houseboat, since it could only land on water. Aerodrome A was a full-size version of a previous steam-powered model designed by Langley that made the first sustained flight of a heavier-than-air machine on May 6, 1896. It rose to a height of 100 feet and flew a little over half a mile in about one and a half minutes. The first trial of Aerodrome A on October 7, 1903 was a failure, as was the second trial on December 8, because the launching was not successful. Due to lack of results, Langley did not receive any additional government funds

the flying field was known by several different, but similar, names: aeronautical experimental station and proving ground, aviation school and experimental station, aviation experimental station and proving ground, aeronautical experimental station, and aeronautical proving ground. All of these names refer to Langley Field.

The Army planned to use funds from its FY 1917 appropriation for construction at Langley Field, but the Comptroller of the Treasury determined this was not permitted because the field was planned for aeronautical experimental activities, rather than general military service.[100] Funding for construction at the proving ground was subsequently included in the Army's 1918 deficiencies appropriation, appropriated in June 1917.

The first military personnel arrived April 18, 1917 to man the field. They were housed initially nearby at Fort Monroe, but soon were quartered at the Sherwood Plantation house on the flying field. The J.G. White Engineering Corporation of New York was selected as contractor. Surveys and clearing of land began in late April 1917. Initial work that followed included temporary buildings, a subsoil drainage system to address the site's high water table and susceptibility to flooding, and the dredging of a channel in the Back River to allow access to planned wharves and boat houses (dredge material was used to fill marsh lands). Trees and bushes were cleared for two dirt "runways" for the "machines."

The architectural firm of Albert Kahn and Associates was employed to develop plans for the Aeronautical Experimental Station and Proving Ground. Professor Ernest Wilby headed Kahn's design team at the site. Kahn's first drawings were included in Specification No. 796, signed August 2, 1917,[101] "For Distributing System Consisting of the Construction of Primary, Secondary Service and Street Lighting Lines, and the Furnishing and Installation of Cut-Outs, Street Lights and Transformers." It detailed Kahn's original layout along the bank of the Back River with a main traffic circle, approached by the Back River bridge, directing traffic northwest to the flight line and northeast to the residential area, headquarters and docks. Two smaller circles were also part of the original design, as well as arced, interconnected streets in the adjacent area. The interior land was left open for the flying field.

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for his aerodrome. Hennessy, **Army Air Arm**, 20-21.

[100]Brown, "Eagles Roost," 75.

[101]Col. Charles L. Weidinger, USAF (Ret.), "The People of Langley, A Historical Chronology of Residents in Officers Quarters Main Cantonment Area, 1983, revised 1986," TMs [photocopy], p.4, Office of History, 1st Tactical Fighter Wing, Langley Air Force Base, Virginia.

A small work force was initially provided for the experimental station, but the original plans changed after the United States entered World War I in April 1917. There were new orders for accelerated construction and a larger work force in August, and again in October. Construction at the site progressed slowly, especially in comparison with the rapid erection of wartime temporary buildings occurring across the country. It was initially delayed because of the problem with appropriation of construction funds, and later "due to the fine quality of the design of the buildings."[102] Buildings designed by Albert Kahn for the Army's first aeronautical experimental station were high-quality, substantial, and permanent. Urgent wartime requirements and slow progress at Langley Field led the Army Signal Corps to relocate its aeronautical experimental station in late 1917 to McCook Field, Dayton, Ohio,[103] where operations began before Langley had completed any permanent buildings.

On August 29, 1917, NACA wrote to General Squier again: "Independent of any further official action in the matter, this committee has been unofficially assigned a very satisfactory plot of ground on the Langley Field, and is now proceeding with the erection of its laboratory. It appears, therefore, as a matter of record, that it might be well for this office to receive from you some suitable statement designating specifically this plot of ground as the one assigned this committee for the purposes indicated." No reply to this request has been located.

Specification No. 796-A, for construction of the Army Aeronautical Laboratory (now Headquarters Air Combat Command, No. 693) was signed in August 1917.[104] A hangar (No. 781) and a machine shop (No. 661) were approved for construction in November 1917.[105] Twenty-six duplex houses for officers were appproved for construction, beginning with the first 20 in December 1917. Plans for bachelor quarters for officers (Lawson Hall) and NCOs (Dodd Hall) were also prepared. The White Corporation was removed as contractor in July 1918, and the Army assumed responsibility for construction. By August 1918, all of these contracts were underway, and the Hampton Langley Field Railway Company began operation.

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[102]"History of Langley Field, Virginia, Inception to 1 March 1935, First Period, 1944," TMs, p. 4, Office of History, 1st Tactical Fighter Wing, Langley Air Force Base, Virginia.

[103]McCook Field was a leased property, operations and personnel absorbed by Wright Field in 1927.

[104]Weidinger, "People of Langley," 3.

[105]Ibid., 4.

REF deleted for 130[106] By October 1918 the overall street layout was complete[107] in what came to be known as the Heavier-than-Air (HTA) Area. The Newport News Daily Press commented that "Langley Field is to be made one of the prettiest, as well as best equipped, flying experimental stations in the country."[108]

During the war, Langley Field was primarily used as a training school for aviators. Langley's wartime responsibilities also included bombing experiments, aerial photography and observation, radio and telegraphy, and testing of foreign aircraft. Flying activity began in the spring/summer of 1917 with the first flying unit formed on the field, the 5th Aviation School, later designated the 119th Aero Squadron. It was Langley's only squadron until December 1917. The U.S. Army's first School of Aerial Photography was established at Langley in October 1917. By January 1918, the first class of "aero-photographers" had graduated and was immediately sent to France. The school was transferred to Rochester, New York in June 1918, although the final training stage in aerial photography, the School of Aerial Photographic Reconnaissance, remained at Langley until 1922. The School of Aerial Observers was formed in March 1918 and designated the Air Service Flying School in August 1918.

The Post War Period
After the Armistice in November 1918, major construction work ceased temporarily. Sixteen of the 26 duplexes planned were completed by that time, but other permanent buildings designed by Kahn and Associates were not completed until after the war. In addition to housing, Langley's first permanent construction included an aeronautical laboratory building, two hangars, a machine shop, several buildings in the civil engineering complex (truck shed, technical stores, etc.), a seaplane hangar, and an officers' club. Only one other major construction project was approved for Langley Field's HTA Area during its initial period of development. The first permanent barracks for enlisted men, Austin Hall (No. 546) was completed in 1924. At that time, two-thirds of the buildings were still temporary wartime construction,[109] but "even

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[106]Col. Charles L. Weidinger, USAF (Ret.), "The Birth of Langley Field," TMs [photocopy], p.3, Office of History, 1st Tactical Fighter Wing, Langley Air Force Base, Virginia.

[107]Weidinger, "People of Langley," 3.

[108]**Newport News (Virginia) Daily Press**, 3 November 1918, quoted in Curtis, **Langley, Early Years**, 14.

[109]Brown, "Eagles Roost," 138, citing "Annual Report of the Chief of Air Service, 1925," 27.

so, Langley was the largest field in the United States,"[110] and, "undoubtedly the finest airplane landing field on the entire Atlantic Coast."[111] In fact, it was the largest and the finest flying field in the entire country, and the only Army airfield with a substantial group of permanent buildings.

Langley Field became a demobilization center after the Armistice. Creation of an Air Service Reserve began in 1919, and flyers, primarily pilots, could continue flying at government expense as an incentive to join. Langley was one of seven fields in the country designated for Reserve flying.

NACA repeated its request for official assignment of space on Langley Field on December 17, 1918. Dr. Walcott wrote to the Secretary of War that the research laboratory was completed and that construction of the wind tunnel building was underway, but "no official assignment of such space has as yet been made by the War Department . . . To complete the records in the case, and to prevent any possible misunderstanding in the future," Walcott requested that Plot 16 (the lot unofficially assigned in 1917) "be officially allotted to the National Advisory Committee for Aeronautics, for use as an experimental field station and for the conduct of scientific research in aeronautics."

The Army's original plans for Langley Field had changed because of the war, however, and the Great War also transformed the organization of the Army air arm. The assignment of space on Langley Field for NACA's laboratory became part of the much larger question of the structure of post-war Army aviation, the subject of lengthy discussion for the next several years. NACA's request for space at Langley Field brought out the ill will felt by some in the Air Service towards NACA. In a January 15, 1919 letter to Maj. Gen. William L. Kenly, the Director of Military Aeronautics, Col. Thurman H. Bane, Chief of the Technical Section at McCook Field,[112] questioned the need for duplicate facilities "for carrying on experimental aeronautical research." His Section strongly recommended "that the control of the field and all experimentation at the field remain with the Air Service . . . Research and experimentation on questions of aeronautics must be controlled and done under the direct supervision of the personnel who are faced with the actual and practical service problems. Research carried on by any other type of organization is liable to beat about long lines that have no immediate practical application to the sacrifice of vitally important matters." Bane also raised the issue of "the dangers of dual

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[110]Curtis, **Langley, Early Years**, 43.

[111]Maj. Thomas DeWitt Milling, "History of Langley Field, June, 1923," TMs (Rough Draft) [photocopy], p.3, United States Air Force Historical Research Center, Maxwell Air Force Base, Alabama.

[112]McCook Field was the location of Army aeronautical experimental activities originally planned for Langley Field.

control" at Langley Field and proposed a conference of NACA members and Air Service representatives to discuss a "satisfactory means of co-operating in the work at Langley Field." His outline for discussion at the proposed meeting revealed his true feelings regarding NACA, however, and included the following excerpts:

> "a. That the National Advisory Committee be reimbursed by the Air Service for buildings and other improvements installed at Langley Field, and that the ownership of these buildings be transferred to the Air Service.
>
> e. That the personnel of the National Advisory Committee shall maintain no equipment of any nature at the experimental station and shall use exclusively such equipment as will be purchased by the Air Service at the joint conference referred to. That the entire personnel of the National Advisory Committee while at the experimental station shall be subject to the orders of the Chief of the Technical Division of the Air Service."

On January 25, 1919, Colonel Bane received a short reply stating that it was "not deemed advisable to bring this point to an issue at the present time," but the "matter may be revived later, when the future of the Air Service is more definitely outlined. We are not yet ready to take over definitely the entire control of Langley Field." Eventually, a conference was called and an agreement was reached. On April 24, 1919, Acting Secretary of War Benedict Crowell approved a Memorandum from Maj. Gen. Charles T. Menoher, Director of the Air Service, recommending "that that portion of Langley Field known as Plot No. 16 be definitely set aside for use by the National Advisory Committee for Aeronautics for their purposes in constructing laboratories or other utilities necessary in scientific research and experiments in the problems of flight." The issue of dual control was resolved by authorizing NACA "to conduct its work independent of the Air Service at that field, except that the personnel and operations of the National Advisory Committee for Aeronautics be under the control of the Post Commander in all matters pertaining to discipline, fire, guard, police and sanitation."

In spite of the official assignment of Plot 16, the wartime relocation of Army experimental activities originally planned for Langley Field made the tenure of NACA's laboratory uncertain. For the next several years, a long-range plan for Army flying fields and depots was under development, and NACA's laboratory was in limbo. Its relocation was pursued seriously due to deficient working and living conditions at Langley Field. In the summer of 1919, Langley Field's disadvantages were stressed in two memoranda to Dr. Joseph S. Ames, chairman of NACA's committee on personnel, buildings, and equipment. The laboratory's engineer in charge of buildings and construction stated that "Langley Field can

never be an efficient or satisfactory place for the Committee to carry on research."[113] Excerpts from a "Memorandum Regarding Use of Langley Field by National Advisory Committee for Aeronautics," (September 27, 1919) by the Committee's secretary John Victory, best summarize conditions at that time:

> "3. The original plans for Langley Field called for a large proportion of civilian scientists and engineers to be quartered on the field. The Chief Signal Officer stated that the scientists and engineers of the Advisory Committee would also be assigned quarters on the Field.
>
> 5. ...the Army has since decided not to use Langley Field as a permanent experimental field. Langley Field therefore has not been completed, and the power house, among other projects, has not yet been erected.
>
> 7. Sufficient power cannot be obtained from the city of Hampton to run the Committee's wind tunnel and engine dynamometer laboratory, therefore necessitating the use by the Committee of temporary means of supplying power.
>
> 8. Civilian quarters have in part been assigned to the Committee's technical employees by the Air Service. The recent decision of the Judge Advocate General of the Army, however, requires the cancellation of this privilege.
>
> 9. Due to the change in location of the Army's experimental activities, the Committee finds it difficult to secure or retain high-grade men at Langley Field. The atmosphere and environment in which they work is not helpful, and there is too little opportunity for the interchange of ideas.
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> 10. The market is poor for labor, supplies, and equipment, and especially poor for even the simplest instruments for use in the laboratory."

To address some of NACA's concerns, Acting Secretary of War Crowell submitted a bill on December 8, 1919 to the Chairman, Senate Committee on Military Affairs, requesting that it be introduced in Congress and given special priority:

A Bill

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[113]John Victory, "The Langley Laboratory," TMs (rough draft) [photocopy], p.10, Langley Historical Archive, NASA Langley Research Center, Hampton, Virginia.

To authorize the Secretary of War in his discretion to furnish quarters at Langley Field, Virginia, to the civilian employees of the National Advisory Committee, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of War be, and he hereby is, authorized, in his discretion to furnish living quarters at Langley Field, Virginia, to the civilian employees of the National Advisory Committee for Aeronautics, to supply them with heat, fuel, and light for such quarters at the actual cost thereof to the Government, and to extend to them the privilege of purchasing subsistence stores and commissarial supplies at cost plus 10%.

The Army and NACA established committees to investigate relocation of NACA's laboratory. From the fall of 1919 into 1921, the Air Service discussed special legislation necessary to transfer the laboratory to Bolling Field in Washington, D.C. "Throughout 1920, relations on the field became more and more strained . . . and the military submitted numerous complaints against the civilian employees . . . The Commanding Officer and General [Billy] Mitchell are anxious to have the Committee move from Langley Field . . . and are inclined to discredit the Committee on the Field."[114]

On June 11, 1920, NACA's laboratory was officially dedicated, in conjunction with completion of its first wind tunnel. The Air Service put on quite a show for NACA's formal opening. "Before a distinguished company of army and navy officers, together with members of the National Advisory Committee for Aeronautics, the new Langley Memorial Aeronautical Laboratory was formally dedicated and opened at Langley Field yesterday morning, with a series of spectacular flying formations . . . A formation flight was held with 25 planes in line, headed by General Mitchell, who is here to witness the tryout of the Johns' multiplane. Two of these were German all metal planes and had been flown from Washington, each carrying a pilot and five passengers. The Zodiac, largest airship in the United States, and the C-3, USN, also participated in the flying circus."[115]

Dr. Ames later expressed his appreciation in a letter to Col. William N. Hensley, Langley Field's Commanding Officer: "The general condition of the field, flights of airships and aerial maneuvers of numbers of airplanes, together with the appearance of the German all metal planes and other planes . . . all combined with the dedication of our laboratory . . . to make the occasion not only one of historic interest for the field, but one long to be

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[114]Ibid., p. 16-17.

[115]**Newport News(Virginia) Daily Press**, 12 June 1920.

remembered by all who were present."[116] Ironically, Hensley had not attended the formal dedication ceremony or allowed any other officers to attend. NACA's laboratory was officially designated Langley Memorial Aeronautical Laboratory (LMAL) at the opening, in honor of Samuel Pierpont Langley, the "father of aviation."

Only a few days later, the Navy expressed interest in utilizing Langley Field for aviation experimental purposes. A June 15, 1920 Navy memorandum discusses establishment of Langley Field, with a follow-up on June 17, 1920:

> "The Navy has need for an experimental station and eventually will have to build one of its own, unless it may use Langley Field in cooperation with the Army . . . Admiral Taylor considers that the claim of the Navy for a portion is very shadowy . . . The Operations group of the Army is very much opposed to letting the Navy on Langley Field in any capacity . . . any attempt would be unsuccessful while the present officers are in charge . . . The Navy, when the field was acquired, made no attempt for a joint participation with the Army in the development of an experimental station and has shown no interest until recently in using it as such."

A staff memorandum (July 14, 1920) to the Director of the Air Service, commenting on the Director of Naval Aviation's recommendation for use of Langley Field as a combined experimental station, noted that "the question as to the use of Langley field as an experimental station has been given very careful consideration in this office during the past year and a half, and as a result of the experience already gained in the use of that station for such purposes, and in view of the Army A.S. program which calls for the use of Langley field as a center for tactical training of various kinds, it is considered that no action should be taken which would require the future use of langley field as a combined experimental station." The Army's post-war development plans had then progressed to the point that the Chief of the Air Service, General Menoher, expected Langley Field to be "such an important post that the Army contemplated in the near future having every branch of the Air Service represented at Langley Field . . . It is very desirable from the Army's standpoint that they have use of all the facilities and buildings at Langley Field."[117] The Navy apparently droppits request to conduct experimental activities at Langley Field. Expiration of the Army's lease on McCook Field led to a search for a new site for the Air Service's experimental labs. On July 24, 1920, NACA Headquarters in Washington, D.C. informed LMAL that its relocation

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[116]Joseph J. Ames to Col. William Hensley, June 21, 1920.

[117]Memorandum, Lewis to Griffith, July 1, 1920.

to Bolling Field would not be pursued until relocation of McCook's experimental laboratories was settled.[118]

Legislation authorizing occupancy of quarters by LMAL personnel (an immediate priority in December 1919), "passed the Senate and was favorably reported to the House on January 25, 1921," but by that time "a condition had arisen which required the surrender of quarters by February 1 . . . [because] the needs of the Air Service . . . require all quarters on the post."[119] General Mitchell attended a special meeting of NACA's Executive Committee on January 27, 1921 to discuss the need for LMAL personnel to vacate Army quarters by February 1, and his willingness to prepare legislation for LMAL's transfer to another location. At the next Executive Committee meeting (February 10, 1921), the question of relocation was tabled until the Air Service took action to provide a new location for McCook's Engineering Division and experimental activities.

Langley Field received a new Commanding Officer in late 1921, greatly improving relations between the co-occupants. "Colonel Danforth's interest in the Committee and belief in the value of our research work is considerable . . . It has already been largely responsible for a very marked change in attitude of other officers upon the Field, and has been of utmost value . . . in securing equipment and general cooperation from Field authorities."[120] The question of LMAL's relocation apparently resolved itself because relocation of McCook's experimental activities was not quickly decided, and conditions at Langley Field were greatly improved. From this point on, NACA's Langley Memorial Aeronautical Laboratory got down to the work for which it had been established, and which had been so long in coming.

LANGLEY FIELD: ARMY AVIATION IN THE 1920S

Langley Field began to assume its place as the center of Army aviation in the late 1910s and early 1920s. Army aviation had been removed from the Signal Corps due to wartime organizational problems, resulting in establishment of the Army Air Service by executive order in May 1918. After the Armistice, an interim organization was authorized for the Air Service while a comprehensive plan for operations and training was developed. By autumn 1919, two wings, seven groups, and 27 squadrons of airplanes had been formed. Langley Field's original aeronautical experimental mission was not restored. Instead, Langley assumed responsibility for coastal defense, and became the headquarters for the

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[118]Memorandum, Lewis to Griffith, July 24, 1920.

[119]Minutes of Special Meeting of Executive Committee, January 27, 1921, p.3.

[120]Victory, "Langley Laboratory," p.19, citing Memorandum, Griffith to Victory, January 5, 1922.

2d Wing, one of the Air Service's two wings. The 1st Army Observation Group was also headquartered at Langley; it was the only observation group on the mainland, and one of four group headquarters in the continental United States.[121] By the spring of 1923, the Federal government's strict fiscal policy reduced the Air Service organization to one wing, which retained its headquarters at Langley Field. The 2d Bombardment Group, the Air Service's only bombardment group, was transferred to Langley in 1922. This gave the field its first tactical units, and began its role as the center of tactical training for Army aviation. One of two airship companies was also stationed at Langley in the early 1920s. Langley Field was the only Air Service station with a substantial number of permanent buildings, and Army aviation revolved around this hub.

The Army Air Service authorized a School of Application at Langley Field on February 25, 1920. This was the first U.S. Army school to provide professional education for air officers and teach the tactics of military aviation. Maj. Thomas DeWitt Milling (the school's first commandant) was ordered to Langley in July 1920 to organize the school and prepare a program of instruction. There was only a limited amount of time and Air Service precedent and doctrine to work with.[122] Completion of pilot training, or balloon and airship pilot training, and one year of service with an Air Service organization were requirements for all students.[123] Three departments were established; the Department of Military Art (Tactical), the Department of Aeronautical Engineering (Technical), and the Department of Administration. The training in tactics was considered the most important, and accounted for half of the scheduled hours of instruction. Courses were designed to qualify squadron and balloon commanders and Air Service officers of higher commands for their duties, not to produce specialists.[124] The school opened in November 1920, and was officially named the Air Service Field Officers School. The first textbook on air tactics, **Air Tactics**, written by faculty member William Sherman in 1921, is "a classic Air Service text on air doctrine."[125] By the end of the second year, a sound administrative and instructional system was established that provided the basis for the school's future expansion.[126] The shortage of field grade officers (major and above) in the Air Service led to a name change in

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[121]Mauer, **Aviation**, 455.

[122]Ibid., 160-161.

[123]Ibid., 159.

[124]Ibid., 160.

[125]Ibid., 594.

[126]Ibid., 161.

November 1922--the Air Service Tactical School. It became the Air Corps Tactical School in 1926. "Most of the important studies and statements of air doctrine during the two decades between the wars"[127] originated at this school, which relocated to Maxwell Field (Montgomery, Alabama) in July 1931.

Regular sessions of the first Field Officers School were terminated early when the class was incorporated into the 1st Provisional Air Brigade in May 1921 to participate in Brig. Gen. William Mitchell's battleship bombing tests. The aerial bombings took place during June, July, and September 1921, about 75 miles from the mouth of the Chesapeake Bay and 100 miles from Langley Field. Targets were a submarine, destroyer, cruiser and battleship surrendered by the Germans, and an obsolete U.S. battleship. Communications between pilots and directors on ships observing the tests marked the first extensive use of airborne radio-telephone equipment. "There were two other places that could have been used . . . Cape Hatteras and Cape Cod . . . But the majority of the Naval officers were so sure the air attacks would prove ineffectual, that it was desired to show as many Congressmen as possible how little could be done by the air force, and as the sea off the Chesapeake was the best place for this, it was chosen."[128] General Mitchell threw a big party at the Langley Officers' Club that night to celebrate his accomplishment (demolished).[129] The aerial bombardment of ships, as well as other bombing tests conducted from Langley during the 1920s, resulted in the teaching of bombardment "as the ultimate aerial weapon"[130] at the Air Corps Tactical School. This doctrine was contrary to the prevailing view of military aviation that pursuit (defensive) planes were the principal weapon of air power, and eventually contributed to the development of the long-range bomber program.

Langley's association with Lighter-than-Air (LTA) aviation began in June 1918 when its first balloon detachment arrived.[131] Construction of an airship (dirigible) station began on the north side of Langley Field in early 1919. A

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[127]Alfred Goldberg, ed., **A History of the United States Air Force, 1907-1957** (Princeton: D. Van Nostrand Co., 1957), 34.

[128]Brig. Gen. William Mitchell, **Winged Defense: The Development and Possibilities of Modern Air Power - Economic and Military** (New York: G.P. Putnam's Sons, 1925), 43-44.

[129]Mauer, **Aviation**, citing **Air Service News Letter**, August 4, 1921, p.14.

[130]Copp, **Great Captains**, 274 and 318.

[131]Merle Olmsted, "Army Airship Operations, Langley Field, 1919-1922," **American Historical Society Journal** 5 (Winter, 1960): 293.

large hangar (420 feet long by 125 feet wide by 116 feet high, dismantled 1947) was constructed to house the airships, and it dominated the north section of the field. Hydrogen (No. 1004, 1919) and helium (1922, demolished) plants, and a compressor plant (No. 1007, 1919) were constructed to provide gas needed for inflation of balloons and airships. More substantial development of what came to be known as the LTA Area occurred in the early 1920s in association with the Airship School established at Langley Field. Approximately 25 buildings were built to house LTA officers and NCOs, most of which has been demolished (Nos. 868, 869, 948 and 949 remain).

During demobilization, only two of the many balloon units arriving at Langley Field were not immediately deactivated, the 19th Balloon Company (arrived July 24, 1919) and the 10th Balloon Company (September 22, 1919). In April 1920, they were designated Airship Companies, when a distinction was made between units with observation balloons and those operating airships. The 10th Airship Company was redesignated again in October 1921 as the Airship School. In June 1922 the Airship School and all airship training were transferred to Scott Field, the Army's principal LTA station at that time.[132] The 19th Airship Company was Langley's only remaining LTA unit until its departure in November 1935 for Moffett Field, California.

Langley's LTA Area was most active during the 1920s. There were more than 17 non-rigid and semi-rigid airships stationed there, as well as many types of free balloons[133](development of rigid ships for U.S. forces was assigned to the Navy). Airship missions included Tactical School training, photography and reconnaissance missions during bombing tests, coastal patrol exercises, Chesapeake Bay area coastal defense, transportation for political leaders, etc. NACA flight personnel also conducted extensive experimental and theoretical work on Lighter-than-Air craft.[134]

Several of Langley's airships were noteworthy. The ZD-US-1 (the "Zodiac") was a non-rigid airship acquired by the Air Service from France early in 1920. It was erected at Langley and was the largest airship in the United States up to that time.[135] The first transcontinental flight by an airship was made by the non-rigid C-2 in summer 1922 from Langley to Ross Field, California.[136] It was blown into the hangar doors at Brooks Field, Texas on the return trip and its

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[132]Ibid., 295.

[133]Curtis, **Langley, Early Years**, 48.

[134]Hansen, **Engineer in Charge**, 55.

[135]Ibid., 50.

[136]Olmsted, "Airship Operations," 297.

gasoline spilled and burned, igniting its hydrogen.[137] An experimental hook-on flight at Langley in 1923 was the first to maintain contact between an airship (the D-3) trapeze and a Sperry Messenger, one of the smallest planes operated by the Army. This flight laid the foundation for later development of the Navy's flying aircraft carriers. The most famous airship ever stationed at Langely Field was the Roma, the largest semi-rigid ever built.[138] It was purchased from Italy and arrived at Langley for reassembly in late 1921. Engine trouble occurred shortly after her first U.S. flight in November 1921 and new engines were installed early in 1922. On the first flight to test her new motors on February 21, 1922, the Roma crashed and blew up. It was the worst air disaster in the U.S. up to that time.[139] Thirty-four of 45 crewmen were killed, and it placed the airship program in jeopardy, as it had little support outside the LTA branch of the service.[140]

A number of significant developments in training for airmen originated and were conducted at Langley Field in the 1920s and early 1930s. Annual bombing and gunnery matches were held at Langley from 1924 to 1932. The competitions were "a national affair where the best machine gun and bombing pilots from the army, navy, and Marine Corps assemble and compete for the honors. [In 1926] there were assembled on the field approximately 100 airplanes and throughout the day bombs were bursting and machine guns firing in five different areas about the field . . . The effectiveness of aerial machine guns on ground troops are clearly demonstrated by these matches. The potentiality of such weapons - aerial machine guns and bombs, are vast and as a weapon of both offense and defense they rank second to none."[141]

Additional bombing tests were also conducted out of Langley Field during this period. In the summer of 1923, Billy Mitchell commanded more operations against warships off Cape Hatteras. Obsolete battleships were used and battle conditions were simulated as much as possible. Langley's 2d Bombardment Group provided most of the planes and personnel. "Training to increase the efficiency of the bombardment personnel of the Army Air Service"[142] was the purpose of

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[137]James R. Shock, Warren, Michigan, to Charles F. O'Connell, Jr., Ph.D., Langley Air Force Base, 28 March 1983, Letter, Office of History, 1st Tactical Fighter Wing, Langley AFB, Virginia.

[138]Olmsted, "Airship Operations," 298.

[139]Curtis, **Langley, Early Years**, 51.

[140]Mauer, **Aviation**, 60.

[141] Virginian-Pilot and The Norfolk Landmark, January 1, 1927.

[142]Mauer, **Aviation**, 124.

these tests; they were not intended to reopen the controversy over the effectiveness of aerial bombs against seacraft. In December 1927, a bridge over the Pee Dee River near Albermarle, North Carolina provided another bombing test of an actual target. Aircraft from the 2d Bombardment Group at Langley formed a Provisional Bombardment Squadron that operated out of Pope Field, North Carolina. Their primary mission was to test the penetration of airplane bombs on a modern concrete structure. Bombing tests conducted from Langley Field during the 1920s provided evidence for General Mitchell's theories, although they did not conclusively settle the question of air power supremacy.

Langley Field also had a pivotal role in Air Service tactical training. In October 1925, all Air Service combat planes and pilots were concentrated at Langley and Mitchel Fields for maneuvers, to provide tactical training of units as an air force. The exercise was successful and led to annual maneuvers until 1931, with a different military problem set for each occasion. In 1928, rather than the usual maneuvers, the Air Corps formed a group at Langley Field to perform aerial operations at Army service schools and promote public support for military aviation. The Langley show for the Air Corps Tactical School included congressmen, other officials, and newsmen. [143] Maneuvers in 1929 in Ohio supported the bombardment doctrine advanced at the Air Corps Tactical School, and pursuit tactics and training changed as a result.[144] "Annual maneuvers, begun by the U. S. Army Air Service in 1925, brought aviation units of the corps areas together for training and operations, to experiment with and test organization, equipment, tactics, and logistics. Maneuvers gave Air Corps officers command and staff experience and practice in handling large units in the field."[145] "Maneuvers and exercises yielded technical data, proved or disproved theories, uncovered new ideas, afforded training not obtainable in any other way and otherwise contributed to the progressive advancement of Army aviation."[146] Tactical training also included cross-country flights of entire groups to test mobility. Langley's 2d Bombardment Group made long distance flights to Bangor, Maine in 1923 and to Mitchel Field in October 1924, and flights were made annually from 1928 to 1930 from Langley to the west coast (Los Angeles, Rockwell Field, Mather Field).[147] These flights also provided significant training and experience for pilots.

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[143]Ibid., 242.

[144]Ibid., 252.

[145]Ibid., 239.

[146]Ibid., 253.

[147]Ibid., 76 and 234.

In the 1920s, Langley Field was also one of the most important stations in the United States for training junior components of the Army Air Corps. It served as the training center for all National Guard and organized Reserve Air Corps units within the Third Corps Area, as well as for some special types of units from the whole eastern U.S.

The Air Corps Board was located at Langley Field during this period. Its function was to enhance the effectiveness of the Air Corps by observing tests, conducting studies, and making recommendations for all matters pertaining to the Air Corps. Langley also served as a demonstration field for the Army air arm in the 1920s, and had many distinguished visitors as a result. "The size of the field and its proximity to the National Capital . . . rendered it somewhat of a show station or a place for Air Corps demonstrations for the benefit of high government officials and agencies. Special demonstrations have been held for committees of Congress as an aid in their study of aviation, and aerial reviews are frequent for persons of sufficient rank or standing to warrant such activities. It is believed that the number of such demonstrations and tests held at the field will increase in the future. These will probably consist of . . . aerial bombing attacks on battleships traveling under their own steam. It has already been proved that bombs dropped from aircraft can hit on or near enough to battleships to effect their destruction. The Air Corps is quite confident of its ability to effect hits on such targets maneuvering under their own steam at full speed. When this is proven by tests, the importance of aircraft in the defense of the nations, which is already of first importance, will be increased."[148]

Langley Field contributed to some significant developments in civil aviation in the early 1920s. The field was part of a model airway established and operated by the Air Service as an example for a nationwide network of airways and landing fields. Scheduled flights over the model airway began in 1922, and Langley provided communications, weather service, and navigational markers as part of the system. Planning for the first flight around the world, promoted by General Mitchell, began in 1923. Crews selected for the first flight received training at Langley, where they were assigned in late 1923. They studied global navigation, survival, engineering maintenance, and evaluated the actual flight plan.[149]

Langley Field: The Langley Memorial Aeronautical Laboratory (LMAL) in the 1920s
The Langley Memorial Aeronautical Laboratory "treated aeronautics not so much as a scientific discipline, but as an area for engineering research and development;" its achievements were "largely the result of practical

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[148]Virginian-Pilot and The Norfolk Landmark, 1 January 1927.

[149]Curtis, **Langley, Early Years**, 53.

engineering solutions."[150] The laboratory's empirical methods and experimental programs were in keeping with the state of early American aeronautics because of the nature of the scientific and technical problems of flight, the inadequacies of theory addressing them, and the scarcity of theoretical aerodynamicists in the United States at that time.[151] Contemporary aeronautical programs at American universities produced practical engineers. The standard testing procedure used by LMAL engineers was experimental parameter variation, a procedure varying one design component at a time, "observing the effects of slight changes made one at a time in planned, orderly sequence."[152] LMAL contributed to gains in aerodynamic efficiency with applied fundamental research.

By April 1921, LMAL was in full operation. Minutes of NACA's semiannual meeting reported "that the personnel employed are competent . . . The research problems being considered at Langley Field have been carefully outlined and planned by the various subcommittees to provide solution of fundamental problems in which both the Army and the Navy are interested, and which have bearing on development of successful types of commercial airplanes . . . In aerodynamics, the subcommittee recommended facilities and staff at Langley Field be employed constantly on a few general problems in order to develop results of general use. General problems for the aerodynamics staff:

a) Comparison between stability of airplanes in flight test vs. wind tunnel measurements

b) similar comparison between performance of full scale planes and wind tunnel experiments

c) general airfoil problems including control surfaces, particularly thick sections."

When LMAL was officially dedicated in June 1920, the laboratory complex included three buildings. The "Research Laboratory" (No. 587), completed in 1918, was the location of administrative offices, drafting, machine/woodworking shops, and photography and instrument labs, as well as a lunchroom on the second floor. The wind tunnel building (No. 580, 1920), which housed wind

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[150]Hansen, **Engineer**, xxviii.

[151]Ibid., xxix.

[152]Ibid, 200. "The method is ancient . . . [and] has been used for so long by so many different types of engineers precisely because it permits solution of a complex problem without a complete understanding of all aspects of the problem." Ibid., 126.

tunnel no. 1, was discussed as follows in NACA's 1921 semi-annual report: "The equipment at Langley Field is most satisfactory, especially the wind tunnel, which is considered the best for the particular type of work for which it is now being used. The wind tunnel is now capable of being operated at speeds in excess of 110 miles per hour and with the installation of a new propeller it is expected to obtain an airspeed of 140 miles per hour. The air flow has been carefully checked and found to be very uniform."[153] The third building was a temporary structure housing the engine dynamometer lab equipment.

The report that praised the wind tunnel also noted, however, that its capacity "is not sufficient to carry through completely the present program of research, and the construction of a new and larger wind tunnel or a compressed air wind tunnel has been discussed." It was to be made as large as possible to eliminate scale effect. "The results obtained from such a wind tunnel can be directly compared with those obtained from a model of the airplane in free flight where the scale of the model is 1/20 . . . The importance of this project cannot be overestimated as the results obtained would place this country a year or a year and a half in advance in obtaining fundamental aerodynamic information which would make it possible to obtain the same advantages in the actual airplane design and construction." The compressed air wind tunnel was formally opened October 19, 1922 at the annual meeting. A Service Building (No. 586, 1925), with drafting room, shops, etc. was completed in 1925. Work done in this small group of facilities on Plot No. 16 at Langley Field, Virginia began a revolution in aeronautical research that was felt around the world.

Langley's aeronautical research progress really began with its compressed air wind tunnel, also known as the Variable Density Tunnel (VDT, formerly located in building no. 582, NHL, 1985). Its design was the inspiration of Dr. Max Munk, a German theoretical aerodynamicist who came to work for NACA in 1921. The VDT was used for all types of aeronautical studies, but testing of airfoils was its main function. A wing is an an example of an airfoil designed to convert air momentum into lift.[154]

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[153]NACA Minutes of Semiannual Meeting, April 21,1921.

[154]Gray, **Frontiers**, 98. "Airfoil is the name for a streamlined shape which is able to harness the momentum of moving air. The term applies to such shapes as propeller blades, tail fins, rudders, ailerons, and wings. If you slice a wing vertically from its nose or leading edge through its rear or trailing edge, you get a shape whose outline is the wing section . . . It was by varying the curvature of the section, particularly the relationship of the curve of the under surface to that of the upper, that the NACA engineers were able to point the way to wings of higher lift and lower drag."

The design of airplane wings was one of the most important research areas in this early period of aeronautical development. Since the 1830s, successful wing designs had been achieved with empirical methods, but misinformation about wings resulted from the cut and try approach. A wind tunnel that could produce reliable measurements was required to conduct systematic airfoil tests and develop a wing design based on scientific principles. The VDT was the groundbreaking facility needed, and the first experiments with a series of wing sections began in 1923. The basis of the experiments was a new airfoil theory of Munk's. This work produced a "major breakthrough, if not a watershed in the history of airfoil design."[155] The 1925 research report introduced NACA's first "family of wings," including several sections "with excellent characteristics . . . . Langley's VDT had established itself as the primary source for aerodynamic data at high Reynold's numbers in the United States, if not in the world."[156]

Munk resigned from NACA in early 1927, following the resignation of all four section heads in LMAL's Aerodynamics Division due to difficulties in working with Munk. By that time, NACA had established a research process for LMAL, replacing Munk's "volatile genius" with "a well-oiled machine that would make aeronautical progress routine."[157] During NACA's early years, its real mission of aeronautical research had become clear, and Langley Field was the location of this research. The priority for LMAL research was investigation of flight conditions and principles basic to all aircraft, rather than testing for specific aircraft design problems.

American civil and military aviation advanced dramatically in the late 1920s. The growth of commercial aviation gave LMAL research a new direction and expanded its research program. Aeronautical problems of interest to the growing aircraft industry were investigated, such as safety, noise reduction, cost reductions for construction, maintenance and aircraft operation, which helped to strengthen the industry and promote expansion of its market. In 1926, NACA initiated an annual conference for aviation leaders that was held at the laboratory. It included a tour of LMAL facilities and a briefing on the Committee's work. Requests for short-term practical research were allowed at the conference, contrary to the standard priority for long-range fundamental studies.

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[155]Hansen, **Engineer**, 81.

[156]Ibid., 84. Reynold's number is the ratio used to correct for scale effect, which provides a rational basis for extrapolating experimental data from scale-model testing to indicate the aerodynamic forces of actual flight. Ibid., 72.

[157]Roland, **Model Research**, 97.

The Second General Conference Between Representatives of Aircraft Manufacturers and Operators and the National Advisory Committee for Aeronautics occurred in May 1927. Its stated purpose was "to secure a discussion of problems involved in the design and construction of aircraft, with special emphasis upon the problems growing out of the needs of commercial aviation, with a view to the incorporation of such problems into the research programs of the National Advisory Committee for Aeronautics for the ensuing year." A suggestion for cowling research made at this conference led to a major aeronautical development. At that time, the most popular powerplant (engine) for military and civilian aircraft was the radial engine with its exposed cylinders. The drag caused by the exposed cylinders was "one of the more urgent questions facing American aeronautical engineers . . . Existing air-cooled designs wasted considerable power; projected into the external airstream for cooling, the finned cylinders of the radial engine caused high drag."[158]

LMAL's newest tunnel, the Propeller Research Tunnel, was nearing completion when the cowling request was received. It could accommodate full-scale testing of propellers. The need for propeller research had become crucial with military demands for higher speeds in both fighters and bombers. Propellers suddenly lost efficiency at high speeds, blades broke under the pull of centrifugal forces, and the limits of safe, economical operation were not known.[159] The PRT was the perfect facility for conducting the cowling investigation. In July 1927 a systematic program of cowling tests was initiated. "The Langley engineers were able to demonstrate that merely enclosing the engine in a metal jacket immediately reduced the drag. . . The jacket was carefully shaped to promote the airflow, and not only was drag reduced but the cooling job was more efficiently performed."[160] The cowling research was published in a November 1928 NACA Technical Note written by Fred Weick, principal designer and head of the Propeller Research Tunnel from 1925-1929. NACA predicted a 60 percent reduction in drag and a 14 percent increase in speed. In February 1929, a Lockheed airplane equipped with the NACA cowling established a new non-stop record flying from Los Angeles to New York. Lockheed wired NACA the next day:

> Cooling carefully checked and OK. Record impossible without new cowling. All credit due NACA for painstaking and accurate research. [signed] Gerry Vultee, Lockheed Aircraft Co.[161]

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[158]Hansen, **Engineer**, 123.

[159]Gray, **Frontiers**, 36.

[160]Ibid., 113.

[161]Hansen, **Engineer**, 129.

NACA won its first Collier Trophy for this achievement based on LMAL's investigation in the Propeller Research Tunnel (PRT).

The size of the PRT's throat (20 feet) was unprecedented, larger than any wind tunnel in the world, and it required a huge amount of power to operate at the necessary speed.[162] The PRT was large enough to allow testing of a real fuselage with its entire engine installation and full-size propeller, making correction for scale effects unnecessary. Test results for propellers were "comparable to those obtained in the variable-density tunnel for airfoil and airplane models."[163] The PRT "proved as revolutionary and effective" as the VDT, and brought three major findings in the course of a few years:

> First, it showed that the exposed radial engine was a source of costly air resistance, and out of these studies came the NACA cowling. Second, it proved that a multi-engine airplane performs best when its engines are in line with the leading edge of the wing and that established the front-of-the-wing position, an arrangement now followed by all manufacturers of multi-engine airplanes. A third contribution was the demonstration of the enormous toll of drag exacted by the landing gear . . . it was not until the NACA had published the results of its wind-tunnel studies that aeronautics had measurements of the inefficiency . . . Retractable landing gear was a rarity fifteen years ago."[164]

"After 1932 nearly all transport and bombing airplanes with radial, wing-mounted engines--including the DC-3, the B-17, and many other famous aircraft of the era that followed--used the NACA cowling and located the nacelles with reference to the NACA data."[165] The PRT also showed that propeller speeds higher than Mach number 0.90 were inefficient as well as dangerous.

After the success of the cowling, Congress authorized a full-scale wind tunnel, as well as a new maintenance building and a tow tank to study seaplanes. The full-scale tunnnel (FST) "would finally cost almost three times as much as all the other buildings constructed at Langley in the laboratory's first 12 years,

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[162]"Neither the Hampton nor the Newport News generating plant was powerful enough to supply the electricity needed to drive the Propeller Research Tunnel, so the NACA arranged to use two 1000-horsepower diesel engines salvaged from a navy T-2 submarine." Ibid., 445.

[163]Roland, **Model Research**, 107.

[164]Gray, **Frontiers**, 37, writing in 1948.

[165]Hansen, **Engineer**, 132.

including three laboratory buildings, the atmospheric tunnel, the variable-density tunnel, hangars, and the propeller-research tunnel."[166] The FY 1930 budget included $525,000 in construction funds to begin work; another $375,000 was appropriated the following year.[167]

The world's newest and largest wind tunnel was completed in May 1931 for just over $1 million, with Depression era labor and materials costs.[168] The FST (No. 643, NHL, 1985) was "big enough to admit a complete airplane, wings and all." It was "three times larger than anything of the kind ever projected," the first tunnel "to be powered by two fans (of propeller type) placed side by side, each of 4,000 horsepower . . . and the first to be built with an oval throat," 30 feet vertical by 60 feet horizontal. Some of its design elements were unprecedented--the permanent steel framework which supports the walls is "outside" like scaffolding to leave interior room "for tunnel space . . . through which the air flows . . . smooth and free of obstructive beams, ribs and bracing." Many structural problems had to be solved to build this first tunnel large enough for a single engine plane to be "mounted and tested in a stream of air hurling past at 129 miles per hour."[169]

The FY 1930 budget also included $208,000 for a towing tank to study seaplanes. LMAL's original research program was expanded to include airplane hydrodynamics in 1929. Research in the 1920s concentrated on the "landplane," but seaplanes generally benefitted from improvements in wings, propellers, engine cowlings, and other 1920s developments as well. Water resistance was the primary problem for seaplane designers and operators when the tow tank was placed in service. "As the wind tunnel demonstrates the laws of airflow, the towing tank demonstrates the laws of waterflow and provides a means of experimenting with various shapes and determining behavior when moving through the water."[170]

The towing tank was long enough (2000 feet by 24 feet wide and 12 feet deep) and had a carriage fast enough (tow speed 60 miles per hour) to simulate the actual take-off conditions of a seaplane. The basin was extended to 2,900 feet in 1937, and the carriage towing speed increased to 80 miles per hour. "Part of the tank equipment is an apparatus for sending waves of various magnitudes over the surface, to simulate rough-water conditions for studies of take-off and landing at sea in heavy weather." Special features were incorporated into the

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[166]Roland, **Model Research**, 108.

[167]Ibid., 349.

[168]Hansen, **Engineer**, 101.

[169]Gray, **Frontiers**, 37-39.

[170]Ibid., 65.

tank's design by Starr Truscott, a naval architect formerly with the Navy Bureau of Aeronautics. "The curvature of the Earth had to be taken into account in its construction, and there were unique features in the mounting of the carriage on the rails, along with other details. The tank was completed in 1931, and in the years since then (1931-1948) most of the flying boats and other seaplanes built in the United States have been studied here." LMAL's "extensive series of researches placed the whole subject of water resistance on a firmer basis, and established fundamental data that could be applied in the design of a seaplane of any specified gross-load capacity or take-off speed."[171]

Langley Field: Army Aviation in the 1930s

Langley Field directly benefitted from the Air Corps Act of 1926 and its Five-Year Program to strengthen Army aviation. The assignment of more personnel and equipment required additional permanent construction at Langley. In contrast to all other Air Corps stations, Langley Field already had a substantial number of permanent buildings. The additional program of permanent construction reflected Langley's status as the focal point of the Air Corps, but it was undertaken in the early 1930s toward the end of the Five-Year Program. Technical construction was initially funded by the expansion program, while the Army Housing Program (1926) addressed the urgent need for permanent housing to replace temporary, deteriorated WWI buildings. Uncompleted projects were cancelled or postponed in 1932 as a result of the Great Depression. They were subsequently carried out with relief appropriations to put the unemployed to work.

The various Federal programs that funded Langley's second phase of permanent construction had different purposes, but they produced a large number of substantial buildings and infrastructure. Almost 75 per cent of Langley's permanent historic housing was built between 1930 and 1934. Major facilities and infrastructure included eleven hangars on the flight line, a hospital, fire station, guard house, theater, gymnasium, church, two officers' clubs, a bridge over the Back River (to replace the original bridge damaged in the 1933 hurricane), and a seawall. In the 1930s, there continued to be no rivals for Langley Field's position as the Army Air Corps' premier airfield.

The Five-Year Program brought many new units to Langley Field. The expanding tactical mission put space at a premium, forcing the Air Corps Tactical School's relocation to Maxwell Field, Alabama in 1931. The 8th Pursuit Group arrived in 1931, Langley's first unit of the pursuit type of combat aviation. It was assigned to Langley's major unit, the 2d Bombardment Wing (the 2d Wing until 1929). The 8th Pursuit Group included four pursuit squadrons. The 2d Bombardment Group was also part of the 2d Bombardment Wing, and it included three bombardment squadrons. In addition to its position as headquarters for the 2d Bombardment Wing (one of three wings for air combat forces established

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[171]Ibid., 65 and 67.

by the Five-Year Program), Langley Field also served as headquarters for the 8th Pursuit Group and the 2d Bombardment Group (two of seven air combat forces groups).

Operations and training suffered from lack of funding in the Great Depression. Langley Field's annual bombing and gunnery matches and the Air Corps annual maneuvers were cancelled; 1931 was the last year for the maneuvers and 1932 the last year for the bombing and gunnery matches. The Air Corps established a navigation school at Langley Field in October 1933, one of only two such schools in the country to qualify pilots for instrument flying. The use of radio communications in tactical training and operations had long suffered from lack of satisfactory equipment. Funding shortages and emphasis on fair-weather flying made instrument training a low priority at that time. Most Air Corps activities in the early 1930s were of a civil nature (disaster relief, rescues, forest fire patrols, etc.), and Langley contributed to efforts of this type when necessary. A new Air Corps responsibility was the training and housing of Civilian Conservation Corps (CCC) workers. By May 1933, 1,200 CCC men were stationed at Langley in a tent camp.

Langley Field played an important role in Air Corps efforts to fly the U.S. mail in early 1934, following cancellation of airline contracts for mail delivery due to fraud. The commander of Langley's 8th Pursuit Group, Maj. B.Q. Jones, organized mail delivery to eight cities in the eastern zone. All-weather flying was not then common practice for the Air Corps, and less than a week was provided to properly equip the airplanes. The installation of radios in 52 aircraft in 48 hours at Langley Field by a crew of 20 mechanics, with no experience as communications or instrument technicians, was characteristic of the efforts underway at the applicable stations and depots.[172] The short-range outcome of Air Corps mail delivery was a fiasco, but the long range outcome introduced a new organizational structure that gave greater autonomy to Army aviation. The reorganization in 1935 further strengthened Langley Field's pivotal position as the key Air Corps station.

The new organization established General Headquarters Air Force (GHQ Air Force), placing all combat aviation under a single command for the first time. Its headquarters (HQ GHQ Air Force) was established at Langley Field on March 1, 1935. Langley was the center of Air Corps tactical aviation during HQ GHQ Air Force's tenure on the field (1935-1941). GHQ Air Force's service test, maneuvers, and exercises were all based at or conducted from Langley Field during this period. HQ GHQ Air Force eventually relocated to Bolling Field, Washington, D.C. for wartime reasons, two months before it was abolished by another reorganization in June 1941. Langley Field was the primary location ever associated with GHQ Air Force, the first real organizational step toward creation of a separate air arm.

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[172]Copp, **Great Captains**, 162.

As Air Corps funding gradually improved in the mid-1930s, training concentrated on long distance flights to Central and South American countries (Panama, Argentina, Columbia, Chile, Mexico, Brazil). All of these flights originated at Langley Field. The 2d Bombardment Group earned two consecutive Mackay trophies, honoring the year's most distinguished aviation event, for "goodwill" flights to Buenos Aires, Argentina (February 1938) and to Chile (February 1939). The flight to Buenos Aires covered 11,952 miles; the flight to Chile provided emergency medical supplies following a disastrous earthquake. Flights to Argentina, Columbia, and Brazil were made by B-17s, the Air Corps' first long-range heavy bomber (the Flying Fortress). The first 12 of 13 B-17s ordered by the Air Corps were assigned to Langley's 2d Bombardment Group in 1937 for service testing. The B-15 and B-18 were also tested at Langley.[173] Langley Field's dirt and grass runways were finally paved in the late 1930s to accommodate these larger, heavier aircraft.

In 1937 the School of Aviation Ordnance was established at Langley for training in supply and maintenance of ammunition, assembly and delivery of ordnance material to combat units, and inspection and repair of armament.[174] In July of that year, Langley received one of three regional squadrons organized to provide weather service, since the Army Meteorological Service did not meet the needs of the Air Corps. The Army Airways Communications System was created in November 1938 to operate radio stations and facilitate air traffic between Army airfields in the United States.[175] One of three regional communication squadrons was activated at Langley, with detachments at airfields in the area.

Langley Field: LMAL in the 1930s

Wind speeds of LMAL tunnels in the late 1920s were representative of contemporary airplane cruising speeds (AWT-50 mph, VDT-55 mph, PRT-100 mph), but they were not adequate for high-speed research. A tunnel that operated at hundreds of miles per hour was a necessity. LMAL's first high-speed tunnel was a tall, vertical, steel tube with a 12-inch throat (1927), installed beside the VDT's pressure tank. The VDT's pressurized air, released every time a model was changed, was used to power the tunnel at speeds greater than 500 miles per hour. The throat was narrowed to 11 inches in 1931 with a gain in speed to 765 miles per hour. This tunnel, and the second vertical jet tunnel, the 24-Inch High-Speed Tunnel (24" HST, 750 miles per hour, 1934),[176] helped to improve

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[173]Mauer, **Aviation**, 356 and 361.

[174]Ibid., 387.

[175]Ibid., 397.

[176]The 24-Inch HST had "Langley's first schlieren photographic system to show compressibility burbles and shock waves in air at high speeds . . . The complex phenomena of the compressibility

airfoils and achieve higher flying speeds. High-speed tests in these tunnels were lacking because they were short (less than a minute since they utilized the sudden release of highly compressed air), and models were very small. Funding for a large high-speed tunnel was pursued to address these deficiencies. It was provided by the PWA as part of relief efforts to address unemployment.

The 8-Foot High-Speed Tunnel, authorized by the PWA in July 1933 and operational in March 1936, was a full-speed companion to the low-speed FST. It was constructed of reinforced concrete (12 inches thick and lined with steel) with a dome-shaped test chamber to withstand air pressures when operated at high speed. "Instead of being contained within a barnlike house, as were the propeller research and full-scale tunnels, the eight-foot quite frankly and openly exposed its structure to the world: a closed tube of reinforced concrete, shaped into a hollow elongated ring, whose interior tapers from a maximum diameter of twenty-four feet to the minimum of eight feet at the test section."[177] The "world's first high-speed tunnel of large size" had an 8,000-horse power motor driving an 18-blade propeller, 16 feet in diameter. It was designed to reach a speed of 500 miles per hour, but "the engineers found they could get 550 m.p.h."[178](in early 1945 the speed was increased to 760 miles per hour). An innovative cooling system had to be designed to address the heat from the energy of the 8,000 horse power fan. A ventilating tower with "an ingenious system of trading hot air for cool" solved the problem, a system later applied to many more powerful tunnels.[179] Complete airplane models with six and-a-half foot wing spans could be tested in the 8-Foot HST. In addition to construction of the 8-Foot High-Speed Tunnel (Facility No. 641, 1936), PWA funds also paid for the 24-Inch High-Speed Tunnel (Facility No. 583, 1934), the 15-Foot Spin Tunnel(Free-Spinning Tunnel, Facility No. 646, 1935), and an Aircraft Engine Research Laboratory (1934).

LMAL had continued Max Munk's VDT program to develop improved airfoils. Research was published in 1933, "Characteristics of 78 Related Airfoil Sections from Tests in the Variable-Density Tunnel". This report introduced NACA's second series of airfoils, the NACA 4-digit series. It provided aircraft

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burble were seen for the first time with the new schlieren system and correlated with the pressure distributions for various wing sections. This new understanding led quickly to the development of improved high-speed airfoils." Hansen, **Engineer**, 452.

[177]Gray, **Frontiers**, 42.

[178]Ibid.

[179]Ibid., 43.

designers with "a whole range of wings from which to choose, as one might select home-furnishings or automobile accessories from a catalogue."[180] The NACA 0230 family of wings, the "two-thirty" family, was the most famous of the 4-digit series, introduced in 1935."[181]

The great amount of airstream turbulence in the VDT gradually came to the attention of LMAL researchers. After the FST was completed in 1930, test results at full-scale made it clear that FST tests were more accurate reflections of actual flight conditions than VDT tests. Competition between LMAL's VDT and FST sections produced a tunnel turbulence factor to compensate for VDT turbulence, but this was seen as a short term solution only. Eastman Jacobs, head of the VDT section, began to push for a new, larger VDT with airstream quality approaching that of the smooth air of free flight. Jacobs thought that a low-turbulence pressure tunnel "would greatly enhance the two related lines of research that the VDT team had long been pursuing: development of new airfoils, and better understanding of the basic aerodynamic relationship between airstream turbulence, boundary-layer flow, and wing performance."[182]

Research into the area of boundary layer flow, led by Eastman Jacobs, was underway while funding for a low-turbulence tunnel was pursued (1935-1937). The boundary layer adjacent to the wing, where smooth (laminar) air flow changes to turbulent flow, was recognized as the great source of parasitic drag. "As the air flowed over and under the leading edge of the wing, it moved at first in smooth undisturbed streams of laminar flow adjacent to the wing surface. But . . . by the time it had traveled fifteen per cent of the wing's chord the flow was predominantly turbulent. The engineers knew that this turbulent flow was the enemy."[183] As LMAL researchers learned more about the boundary layer, they realized they needed more than an improved tool (the proposed tunnel). The experimenters needed "a new approach to the problem, some guiding theory that would point . . . to a practical way of prolonging laminar flow."[184] The new approach they were seeking, an airfoil with progressively falling pressure across the chord, was the inspiration of Eastman Jacobs. "This concept changed the whole manner of thinking on the problem. Heretofore, engineers had thought in terms of the shape of the wing, but now it was the pressure distribution that came first. The idea was to plot a curve of pressure distribution that theoretically should promote laminar flow, and then design a wing section that

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[180]Roland, **Model Research**, 540.

[181]Ibid.

[182]Hansen, **Engineer**, 104.

[183]Gray, **Frontiers**, 104.

[184]Ibid.

would induce that sort of pressure distribution."[185] Contemporary airplane wings were a long way from providing the pressure distribution envisioned by Jacobs. Existing theory allowed calculation of pressure distribution from a known airfoil shape, but it did not operate in reverse.[186] Jacobs and his team explored this idea while NACA efforts to secure funding for a low-turbulence pressure tunnel continued.

Two new tunnels had received funding while the laminar research program was underway--the 19-Foot Pressure Tunnel (a super PRT, authorized 1936, operational 1939)[187] and an icing tunnel (authorized 1937, operational 1938). Both resulted from industry demands for specific research, which overpowered LMAL's priority for a low-turbulence tunnel. Ice tunnel research to satisfy industry needs was accomplished in a short time, however, and the ice tunnel was immediately converted to a low-turbulence tunnel. In the spring of 1938, Jacobs' group had a breakthrough in their efforts to design an airfoil with progressively falling pressure across the chord. The new pressure distribution concept was verified theoretically, and manufacture of a wind tunnel model was rushed through the LMAL shop.[188] Tests began in June 1938 upon conversion of the ice tunnel to the low-turbulence pressure tunnel.

"The new airfoil showed a drag on the order of one-half that of the conventional airfoil."[189] The first airplane to utilize LMAL's laminar-flow airfoil was North American Aviation's P-51 Mustang. "The Mustang's war record confirmed the expectations of appreciable improvements in speed and range as a result of the low-drag design . . . The Mustang's modified 4-series section, with its pressure distributions and other features, proved an excellent high-speed airfoil."[190] Eastman Jacobs, LMAL's "leading experimentalist," was "the

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[185]Ibid., 105.

[186]Ibid., 105.

[187]This tunnel combined large size and high pressure in a single facility for the first time. Its speed was too slow for high-speed propeller research, however, and it was converted to the Transonic Dynamics Tunnel, 1955-1959. Donald D. Baals and William R. Corliss, **Wind Tunnels of NASA** (Washington, D.C.: National Aeronautics and Space Administration, 1981), 29.

[188]Hansen, **Engineer**, 114.

[189]Ibid., 114, quoting Jacobs, "Notes on the History of the Development of the Laminar-Flow Airfoils," 27 Dec.1938, A173-1, LCF.

[190]Ibid., 117-118.

inspiration and driving force behind the entire laminar-flow program."[191] In 1937 he received the Sylvanus Albert Reed Award "for his contribution to the aerodynamic improvement of airfoils in military and commercial aircraft" from the Institute of the Aeronautical Sciences."[192] "No one working in the U.S. in the 1930s, perhaps the world, surpassed his ability to develop airfoils by a combination of theory and experiment."[193]

The first low-turbulence tunnel, the Two-Dimensional Low-Turbulence Tunnel (Facility No. 583, 1938), utilized "two devices to straighten the airflow and strain out the eddies . . . It was built as an experimental model to try out the idea of radical contraction and screening, to see if the combination really would lower the turbulence. It did, and the researchers began to plan a larger and still more radical tunnel."[194] The Low-Turbulence Pressure Tunnel, constructed 1939-1941 (Facility No. 582A), was larger, built of steel, and could compress air to ten atmospheres. Its turbulence was less than one-hundredth that of the original VDT.[195] "With the completion of the low-turbulence pressure tunnel in June 1941 the investigators had at their service an incomparable tool"[196] for developing laminar-flow airfoils. "The low-turbulence tunnels were designed primarily for the development of airfoils, and out of them came the first low-drag wings . . . [however], the experiments which produced the two low-turbulence tunnels at Langley also contributed to the design of subsequent tunnels both there and at other laboratories."[197]

Langley Field: LMAL and World War II
In 1939, the Federal government authorized an unprecedented expansion of aeronautical facilities in anticipation of war. LMAL's expansion was provided for by a War Department grant of property located several miles northwest of

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[191]Ibid., 114.

[192]**Significant American and International Awards in Aviation**, 1954, 77. Established by Dr. Reed in 1933, "for a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations, the beneficial influence of which on the development of practical aeronautics is apparent."

[193]Hansen, **Engineer**, 108.

[194]Gray, **Frontiers**, 48.

[195]Ibid., 48.

[196]Ibid., 107.

[197]Ibid., 48-49.

the original laboratory site. It became known as the West Area, and the original location was named the East Area. Several new facilities were authorized for LMAL to investigate special characteristics and problems of military planes. One of the four facilities, a spin tunnel (Facility No. 645, 1940) to evaluate an airplane's ability to recover from a spin, was built at LMAL's original location at Langley Field. The three other facilities were constructed in the new West Area (a structures research laboratory, two high-speed tunnels). Other specialized facilities that were part of the wartime expansion program at LMAL included a free-flight tunnel (Facility No. 644, 1939, to study tailless airplanes, flying wings, and other unconventional types),[198] a second towing tank (Facility No. 720B, 1942) built alongside the existing tow tank, and a seaplane impact basin (Facility No. 720A, 1943).

Priorities of the coming war directed LMAL's research program well before the U.S. declared war. Approximately 50 percent of LMAL's fundamental research had been displaced by military requests by late 1940; military projects represented 71 percent of the research just before Pearl Harbor.[199] Even with LMAL's substantial personnel increase (less than 500 pre-war to over 3,200), and an $8 million construction program (primarily in the new West Area), the workload was overwhelming. NACA's long-standing mission of basic scientific research was replaced with applied research, the "testing, cleanup and refinement of military prototypes of immediate use in the war."[200]

In April 1938, LMAL received an urgent request from the Navy's Bureau of Aeronautics for a general checkup of the Brewster XF2A-1 Buffalo, a new experimental fighter. LMAL had one week to determine "what drag reduction may be expected from changes that can readily be incorporated in the event that this type is put into production."[201] In addition to airfoil shape, turbulence in the boundary layer is also caused by rough surfaces on airplane wings. The drag clean-up test, as it was called, was undertaken "to spot the 'kinks' and 'bugs' that get into an airplane as a result of faulty design, or defects that come about as a result of manufacturing processes. The test reveals the

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[198]Ibid., 50.

[199]Roland, **Model Research**, 178.

[200]Ibid., 167.

[201]Hansen, **Engineer**, 194. "The resistance of an airplane wing to airflow is called the 'induced drag,' and it is an inevitable price that must be paid for lift." Gray, **Frontiers**, 101. But every airplane also has "an additional resistance which the engineers label 'parasite drag' . . . this drag preys upon power. It reduces speed, climb, ceiling, range, and . . . pretty well determines the performance of the airplane." Ibid., 103.

differences between the ship as conceived and as built. It also detects faults in design, and puts a finger on places where the airplane may be improved."[202] Drag cleanup for the Brewster Buffalo was conducted in the Full-Scale Tunnel.

> "The FST team concluded that Brewster had in fact overlooked the aerodynamic importance of several small but highly significant details of the Buffalo's design. The landing gear, exhaust stacks, machine-gun installation, and gunsight all projected outside the smooth basic contour of the aircraft in such a way as to produce unacceptably high drag. By modifying the XF2A-1 in these and several other minor particulars . . . the top speed of the prototype could be increased by 31 miles per hour to 281, more than a 10 percent improvement in performance.
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> The XF2A set two precedents. It was the first airplane to use NACA's new 230-series airfoils. All high performance American military planes built through the end of World War II, with the exception of the P-51 Mustang, employed an airfoil from this efficient series. Second, Langley did such an outstanding job reducing the drag of the Buffalo that the army and navy were soon sending all of their new prototypes to the lab for drag cleanup. Between April 1938 and November 1940 LMAL gave 18 different military prototypes thorough goings over in the FST to see if the airplanes could be bettered in any particular."[203]

The wartime mission of the Langley Laboratory was "to find practical ways for American aircraft to achieve improved performance, i.e., higher speeds and altitudes, longer range, more maneuverability, and better handling characteristics . . . Though all aircraft used by the United States in combat were designed to the same basic formula (internally braced, all metal monoplane, equipped with retractable landing gear, wing flaps, controllable pitch propeller, and enclosed compartment for the crew), they differed widely and significantly in terms of their aerodynamic details. It was thus essential to refine aircraft on a case-by-case basis as problems arose."[204] LMAL's drag clean-up testing continued throughout the war and was primarily the function of the Full-Scale Tunnel, although "this program of specific configuration tests was of unprecedented proportions for the NACA laboratory."[205] It required "precisely the kind of systematic wind tunnel work that Langley did best. The

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[202]Gray, **Frontiers**, 121.

[203]Hansen, **Engineer**, 195.

[204]Ibid., 219.

[205]Ibid., 196.

lab had derived its original family of airfoils in the VDT, and its first low-drag cowlings in the PRT, according to the method of experimental parameter variation; similarly, it cleaned up the drag problems of the American military aircraft that fought World War II. One of the clean-up test's most dramatic improvements was achieved with the P-39 Airacobra. Its speed of 340 miles per hour was raised to 392 miles per hour.[206]

In addition to drag clean-up, LMAL addressed a number of other military aircraft design problems during World War II. "In all, Langley tested 137 different airplane types between 1941 and 1945, representing more than half of all the types contracted for by the army and navy during the war and including virtually all types that actually saw combat service."[207] Langley solutions to specific problems included a wing flap that made recovery from a high speed dive possible, and a modified tail arrangement and antispin device for the Vought F4U-1. LMAL research in the towing tanks and seaplane impact basin produced a hydroflap that aided the ditching of airplanes (the emergency landing of a land-based airplane on water).[208] In September 1944, LMAL conducted one of NACA's more extraordinary flight-research projects in cooperation with the Army, the only experimental full-scale ditching of an aircraft during the war.[209] A ditching test was needed to confirm test data, utilizing models, from the towing tanks. Col. Carl F. Greene had pushed the ditching test as a way to promote life safety of aircrews in planes forced down at sea. He was one of two Army officers who flew a B-24 into the James River for the test. Although the plane was extensively reinforced, it was damaged severely. The B-24 did not split in half, however, as had previously happened during ditchings. Colonel Greene, "one of the true pioneers of aviation engineering in the Army"[210] received the Air Medal in 1945 for meritorious achievement in the ditching test.

Most of NACA's high-speed propeller research during the war was conducted at LMAL in the 8-Foot HST and in the 16-Foot HST (a new facility in the West Area). Propellers were generally thought of "as the most efficient component of the airplane"[211] at pre-war cruising speeds of 300-350 miles per hour, but the demand for higher speeds presented new problems for propellers. Experiments in

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[206]Gray, **Frontiers**, 123.

[207]Hansen, **Engineer**, 219-220.

[208]Ibid., 219.

[209]Ibid., 545.

[210]LMAL Air Scoop, September 21, 1945, p.2.

[211]Gray, **Frontiers**, 208.

1938, using the laminar-flow airfoil theory produced an entirely new family of propeller airfoils, designated the 16-Series. "Tests showed that propeller blades made in these shapes would retain their propulsive efficiency at exceptionally high speeds . . . The 16-Series became the preferred pattern for high-speed propeller blades"[212] during the war. "Although several types of airfoils have been developed and tested since the 16-Series originated back in 1938, none has measured up to it in performance. The 16-Series is still the first family when it comes to speed. It is the designer's only choice as to airfoil type if he is interested in performance at or beyond 500 m.p.h."[213]

Instruments to measure and record wind tunnel and flight test data advanced rapidly during the war years. Prior to World War II, wind tunnel measurements were made almost exclusively with scales or balances (in the pre-war period, scales advanced from common platform scales attended by researchers to supersensitive scales with tapes to print out measurements). Self-recording instruments to measure and record flight research tests were first developed by NACA engineers in the early 1920s. Before the war, mechanical means to record measurements, primarily photography, were generally used. "When the war came, the wisdom of having [a] series of standardized instruments was immediately vindicated. So many, such varied, and such ingenious devices could hardly have been improvised to meet the rapidly mounting needs of emergency research . . . The experience of twenty years of invention lent itself to the development of new means of measuring and recording,"[214] and the adaptation of existing devices to new requirements.

Aeronautical advances required more accurate measurements and more sensitive, standardized instruments. Increased flying speeds required instruments with electrical, rather than mechanical, systems for flight research. The wire strain gauge was an electrical instrument widely used during the war. It measures "the stress that a structure undergoes as a result of the imposition of force . . . It is possible to get a simultaneous record of the strains endured by the wing at any stage of a flight, at take-off, in maneuvering, diving, landing. Strain gages are used on tails, propeller blades, engine cylinders, crankshafts--wherever there are stresses whose magnitude it is important to know."[215] Instruments for measuring airspeed and altitude did not function properly in high-speed dives because of compressibility effects, which led to a "pioneering" series of flight tests at LMAL in 1944. Airplanes dived from high altitudes at high speeds were followed by radar installed on the

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[212]Ibid., 211.

[213]Ibid., 215.

[214]Ibid., 52-53.

[215]Ibid., 53.

ground, which continuously measured the aircraft's position during the test. "This gave an exact record of the flight path and a means of calibrating the airspeed and altimeter recorders . . . Since these pioneering studies of 1944, electronic instruments have become indispensable for research with objects moving in the air at supersonic speeds."[216]

The war brought instruments originally used in flight research into the wind tunnels, and also required development of entirely new instruments for wind tunnel research. In the free-flight tunnel (No. 644, 1939), airplane models actually fly in the windstream. The Instrument Research Division developed an automatic control device that responded to a light at the end of the tunnel to reduce crashes into the tunnel wall. Instrument designers also developed a magnetic control system for the spin tunnel (No. 645), that allowed spin investigators to control models until they reached the stage of spin that was to be recorded.

Langley Field: Army Aviation and World War II

The threat of war in Europe and the Far East produced an unprecedented expansion of the Army Air Corps in 1939. Langley Field saw a large increase in personnel and aircraft, and a massive program of temporary construction was required to accommodate the rapid growth. Most of this development was located west of Langley Field's original acreage, on land specifically acquired for the expansion, the former Shellbank plantation. In February 1941, the 770-acre plantation was purchased from the Hampton Normal and Agricultural Institute, which had been using the site as an agricultural school since the late 19th century. Wartime construction on the property was well underway prior to its final purchase, due to the urgent conditions. Ninety-six buildings were completed by November 1941, as well as heating, electrical, water, sewage and road facilities.[217] A few scattered examples of these temporary buildings remain in Shellbank and the HTA and LTA Areas.

Langley Field lost its position as the Air Corps' center of tactical aviation with the transfer of GHQ Air Force headquarters to Bolling Field in March 1941. Another reorganization of the Army air arm in June 1941 replaced the Army Air Corps with the Army Air Forces. Langley Field became an installation of the 1st Air Force, and the headquarters of the 1st Bomber Command. The 1st Bomber Command (formerly the 2d Bombardment Wing and the 2d Wing, also headquartered at Langley), was activated to control all bombardment and fighter units. The headquarters was at Langley from September 1941 until January 1942, with responsibility for Army Air Forces antisubmarine operations. When the Antisubmarine Command replaced the 1st Bomber Command in January 1942, the headquarters was transferred.

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[216]Ibid., 54.

[217]Curtis, **Langley, Early Years**, 135.

Langley Field played a critical role in defense of the Atlantic seaboard immediately after Pearl Harbor and into 1942. Antisubmarine patrols were conducted daily, as the extension of the U-Boat counterblockade in the eastern and northern Atlantic into American waters was a key part of German strategy. The effectiveness of these patrols (including some attacks) led to relocation of enemy submarine activity to the Gulf of Mexico and Caribbean by May 1942. German submarine activity on the east coast was minimal by September 1942.[218] Langley's 2d Bombardment Group, which had conducted antisubmarine operations since U.S. entrance into the war, was transferred in October 1942 due to the organization of the Antisubmarine Command earlier that year. The 2d Bombardment Group was one of the Army air arm's basic tactical units and one of Langley Field's most prominent organizations. Its transfer marked the end of an era at Langley Field, and ended the longest period of residence (20 years) by any unit during Langley Field's historic period of significance. Antisubmarine patrols from Langley Field continued until September 1943.

All operational training in the Antisubmarine Command was the responsibility of Langley's 18th Antisubmarine Squadron. It was conducted for antisubmarine crews at the operational training school established at Langley in December 1942.[219] The 1st Sea Search Attack Group was activated in June 1942, to develop tactics and techniques of antisubmarine warfare, and develop and test equipment to aid detecting, tracking, and destroying surface or underwater craft. The experimental testing and demonstrations, often conducted during patrols, also gave the unit a training role.[220]

All responsibility for coastal defense was assigned to the Navy in September 1943. Subsequently, Langley Field assumed a pivotal role in the development of radar bombing, as Army aviation began to recognize its potential. Langley's primary function became the training of combat crews in radar techniques (high and low altitude bombardment), as well as the instructors who provided the training.[221] "High altitude bombardment . . . was one of the most important bombardment training projects of the First Air Force."[222] Langley also served as the final staging area for processing radar-equipped aircraft and their replacement radar crews. As the war shifted from Europe to the Pacific, the

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[218]United States Air Force Historical Division. "Brief History of Langley Air Force Base, 1917-1957, May, 1957," TMs [photocopy], pp. 12-13, USAFHRC, Maxwell AFB, Alabama.

[219]Ibid., 14.

[220]Ibid., 15.

[221]Ibid., 16-17.

[222]Ibid., 18.

need for radar equipment and development of its uses increased, as did the need for training in radar operation and maintenance. Langley Field became the Army Air Forces' training center for airborne radar equipment, training radar equipment operators, crews to handle radar-equipped airplanes, radar equipment mechanics, and radar intelligence officers.[223] This technical training continued until the end of World War II.

Langley Field: Army Aviation and the Postwar Period
After the war ended in August 1945, Langley Field's radar training shifted to other bases. Langley had no official mission for several months, and personnel dropped by 25 percent. The Eastern Flying Training Command assumed jurisdiction in October 1945. On December 1, 1945, Langley was transferred to the Army Airways Communication Systems, and the Army Airways Communications Systems (AACS) Wing Headquarters was established at Langley on January 21, 1946. AACS headquarters planned and directed the postwar communications systems serving the Army Air Forces. Headquarters for the Army Air Forces Weather Service also arrived in January 1946. AACS was dissolved in March 1946, briefly placing Langley Field under the jurisdiction of the Air Transport Command.

Tactical Air Command (TAC) was organized in Tampa, Florida, on March 21, 1946. TAC headquarters was established at Langley in May due to its location near Headquarters Army Ground Forces at Fort Monroe, and Headquarters Atlantic Fleet at Norfolk. TAC's mission required cooperation with naval, land and amphibious forces. Langley saw a steady increase in strength as tactical units began to relocate to the base. These units eventually formed the 363d Reconnaissance Group (later Tactical Reconnaissance), with responsibility for combat reconnaissance, and training for combat proficiency in photographic and visual reconnaissance. Headquarters for the 363d Reconnaissance Group was established at Langley in late 1947.

The historic period of significance for Army aviation at Langley Field ends in 1947. A major organizational change occurred when the National Security Act of 1947 created the Department of the Air Force on September 18. The arrival of jet aircraft at Langley in late 1947 with the 363d Reconnaissance Group initiated a dramatic change in operations. In January 1948, Langley Field became a part of American aviation history with its transfer to the Department of the Air Force and its redesignation as Langley Air Force Base.

Langley Field: LMAL and the Postwar Period
This section will cover LMAL's development of transonic tunnels and the period 1946-1958, when NASA replaced NACA. To be continued . . . .

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[223]Ibid.

National Significance

The Langley Field Historic District has national significance in the areas of Military, Science and Engineering, and Education. The following sections document national significance in these areas. Some of the information was covered in previous sections of this nomination, but has been repeated to establish national significance.

MILITARY

The origin of Langley Field as the Aeronautical Experimental Station and Proving Ground for the United States Army Signal Corps is unique in the history of American military aviation. The establishment of Langley Field is also unique as a joint civil-military research facility that included the National Advisory Committee for Aeronautics (NACA, the Federal agency that was NASA's predecessor). NACA's first aeronautical laboratory was located on part of the site purchased for the Signal Corps in December 1916, where NASA operations continue to this day (the significance of this laboratory will primarily be discussed below, under Science and Engineering).

The land acquired for Langley Field was the first property purchased by the Federal government for military aviation.[224] "The selection, acquisition and establishment of the Langley Field site saw several significant precedents set. Not only was Langley Field the first air installation for which the government purchased land, it was the first time the Army cooperated with other agencies in such an endeavor . . . The founding of Langley Field was also the first time a local citizens group would play a significant part in the selection and acquisition of a site for an Army airfield. In future, this would become accepted practice."[225] Langley is the oldest active base in the United States Air Force, with the possible exception of Kelly Air Force Base, San Antonio, Texas.

No orders were published to officially activate bases in the early years of Army aviation, and there are no comparable criteria for Langley Field and Kelly Field that can definitively establish which historic field is "the Air Force's oldest active base." Langley and Kelly are the only extant **active** Air Force bases that remain from the pre-World War I era-both were "under construction in

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[224]Mauer Mauer, Maxwell Air Force Base, Alabama, to John Lumpkin, Langley Air Force Base, Virginia, 17 April 1963, Letter, Office of History, 1st Tactical Fighter Wing, Langley AFB, Virginia.

[225]Brown, "Eagles Roost," 59.

April 1917."[226] Langley originated as an experimental station and proving ground and construction of its substantial permanent buildings was slow. Kelly was established as a temporary installation, on leased land, and construction of six hangars began March 27, 1917.[227] The Secretary of War approved the land purchase on October 12, 1917,[228] and construction was well advanced by time of purchase. Kelly was not selected as a permanent field until after the Armistice.[229] Four planes landed at Kelly for the first time on April 9, 1917. Langley's first personnel arrived April 18, 1917. Camp Kelly was redesignated Kelly Field on July 30, 1917. The Aeronautical Experimental Station and Proving Ground, known as Langley Field even before its purchase December 30, 1916, was officially designated Langley Field on August 7, 1917. Research to date has not established if there are any historic buildings or structures remaining at Kelly Air Force Base that are associated with the earliest period of the air arm's development.

Langley Field's original mission as a large aeronautical experimental station changed because of World War I, and in 1919 it became a fully operational installation of the Army Air Service. Subsequently, Langley played a critical role in the organizational development of the air arm of the U.S. Army, as well as the development of Army aviation operations and training. In the 1920s and 1930s, Langley Field was the center of bombardment and tactical operations for the Army air arm. Organizational developments that eventually led to establishment of the United States Air Force as a separate arm of the military services were initially implemented at Langley Field. The establishment of General Headquarters Air Force was the first real step toward creation of a separate air arm, and its headquarters was located at Langley Field from 1935-1941, a pivotal period in the organizational development of Army aviation.

Langley Field was an integral part of the development of American military aviation due to its role in the operations and organizational structure of the Army air arm. By the fall of 1919, Langley Field was the headquarters of one of the Air Service's two Wings. It was also Headquarters for the 1st Army

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[226]Robert Mueller, **Air Force Bases, Vol. I, Active Air Force Bases Within the United States of America on 17 September 1982** (Washington, D.C.: Office of Air Force History, United States Air Force, 1989), iii.

[227]Edna S. McGaffey, "History of Kelly Air Force Base, Texas From March, 1917 to August, 1955," TMs [photocopy], United States Air Force Historical Research Center, Maxwell Air Force Base, Alabama.

[228]Ibid.

[229]Ibid.

Observation Group, one of the Air Service's four Group headquarters and the only observation group on the mainland (three other observation groups were located in the Philippines, Hawaii, and Panama). During the 1920s, most of the Air Service's strength was in observation units; total offensive strength was one attack, one pursuit and one bombardment group.[230] By the mid-1920s, Langley was the home of one of two airship companies,[231] and one of the country's seven air stations used for Reserve training. Following Army reorganization in 1926, Langley was the Air Corps's only Wing headquarters, Headquarters 2d Bombardment Group (the only bombardment group), and home of the only airship company.[232] Langley's 2d Bombardment Group was one of the Air Service's three full combat groups in the early 1920s, a basic tactical unit of the Air Service, Air Corps and Army Air Forces generally credited with the development of U.S. heavy bombardment. Its twenty-year tenure on the field, from 1922 to 1942, was the longest of any combat unit during Langley's historic period.

Bombing tests conducted by Langley in the 1920s challenged the prevailing view that Army aviation's primary function was to support ground troops as an auxiliary service. In 1921 and 1923, aerial bombardment of ships was directed by Brig. Gen. William Mitchell, Assistant Chief of the Air Service. He was an outspoken proponent of the importance and effectiveness of air power, and the need for an air force co-equal to the Army and the Navy. Shortly after his appointment as Assistant Chief of the Air Service, Mitchell proposed a test of planes against ships, since there were too few examples of aerial attacks on warships to prove his belief that battleships were obsolete. "There were two other places that could have been used . . . Cape Hatteras and Cape Cod . . . But the majority of the Naval officers were so sure the air attacks would prove ineffectual, that it was desired to show as many Congressmen as possible how little could be done by the air force, and as the sea off the Chesapeake was the best place for this, it was chosen."[233] The sinking of the German battleship Ostfriesland on July 20-21, 1921 was the climax of the Naval Ordnance Tests. It was witnessed by a number of foreign observers, reporters and distinguished guests, including the Secretaries of War and Navy, General Pershing (Army Chief of Staff) and General Menoher (Chief of the Air Service), senators and representatives.

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[230]Goldberg, **History of Air Force**, 21.

[231]Mauer, **Aviation**, 455-457.

[232]Mauer, **Aviation**, 461.

[233]Brig. Gen. William Mitchell, **Winged Defense: The Development and Possibilities of Modern Air Power - Economic and Military** (New York: G.P. Putnam's Sons, 1925), 43-44.

These landmark tests aggravated the rivalry between the Army and the Navy, but did not result in autonomy for the Army's air arm or conclusively answer the question of Amry aviation's effect on sea power. They did, however, demonstrate that military aviation was a powerful striking force on its own, encouraged revision of pursuit (defensive) aviation doctrine, and fueled the drive for air arm independence. Another indication of their importance was the Navy's subsequent conversion of the U.S.S. Jupiter (a ship used to transport coal) to the first aircraft carrier, the U.S.S. Langley. The timing of the U.S.S. Jupiter's conversion (U.S.S. Langley launched March 1922, following bombing tests in summer 1921) appears to be related to the Naval Ordnance Tests, but the conversion actually was authorized in the Naval Appropriation Act of 1920. The U.S.S. Jupiter sailed to Norfolk, Virginia in March 1920 for its transformation, which took a year longer than planned.[234] "It cannot be said with any certainty that the Mitchell affair had any direct influence on U.S. naval thinking; battleships continued to be commissioned, but from roughly the same time as the controversial 1921 bombing tests, the U.S. Navy began increasingly to take naval aviation seriously. The Bureau of Aeronautics was formed in September 1921 . . . solely to look after naval air interests."[235]

In the summer of 1923, General Mitchell directed more bombing tests against warships off Cape Hatteras "to increase the efficiency of the bombardment personnel of the Army Air Service."[236] In December 1927, a bridge over the Pee Dee River near Albemarle, North Carolina provided another bombing test of an actual target. The primary mission was to test the penetration of airplane bombs on a modern concrete structure. This test was believed to be "second in importance only to the battleship bombing in 1921."[237] Results of the bombing tests interested tacticians and theorists at the Air Corps Tactical School, and showed the need for much greater bombing accuracy.[238]

Lighter-than-Air operations at Langley Field were also exceptional. Record-setting flights and experiments were conducted with Langley airships, including the first transcontinental flight by an airship in 1922.[239] Some of the Air Service's largest airships were stationed at Langley. Its helium plant was the

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[234]Brian Johnson, **Fly Navy - The History of Naval Aviation** (New York: 1981), 121.

[235]Ibid., 125.

[236]Mauer, **Aviation**, 124.

[237]Mauer, **Aviation**, 225.

[238]Ibid., 226.

[239]Olmsted, "Airship Operations," 297.

only one owned by the Air Service in the early 1920s, and it was one of only two in the United States at that time.[240] One of Langley's airships was involved in the Air Service's worst air disaster,[241] which was also the worst in the United States up to that time.[242] In February 1922, Langley's dirigible Roma, the largest semi-rigid ever built,[243] crashed and exploded on her first flight after installation of new motors. Thirty-four of 45 crewmen were killed, placing the airship program in jeopardy from which it never really recovered.[244] Loss of the Roma hastened use of the more expensive, but non-flammable, helium for Army and Navy airships. The tragedy also led to non-rigid airships as the standard for the Army.[245]

The Air Corps Act of 1926 and its five-year expansion program (1927-1932) to strengthen the Air Corps emphasized Langley Field's role as the hub of Army Air Corps tactical aviation. In addition to being the headquarters for the 2d Wing and the 2d Bombardment Group, it also became the headquarters for the 8th Pursuit Group. Its flying strength was greater than any other Air Corps station.[246] Langley Field's importance was increased even further by the establishment of General Headquarters Air Force (GHQ Air Force) and its headquarters at Langley Field in March 1935.

GHQ Air Force brought all Army combat aviation together under one commander for the first time in the history of American military aviation (pursuit, bombardment and attack units). This "gave the Air Corps an opportunity to demonstrate the doctrine of offensive air power which General Mitchell and his followers had long advocated as a basic concept of modern military strategy."[247] It formalized the shift from "air service" (auxiliary to ground forces) to "air force" (a separate element with a separate mission),[248]

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[240]Curtis, **Langley, Early Years**, 50, citing **Air Service News Letter**, Vol. 5, No. 38, p.6.

[241]Olmsted, "Airship Operations," 300.

[242]Curtis, **Langley, Early Years**, 51.

[243]Olmsted, "Airship Operations," 298.

[244]Mauer, **Aviation**, 60.

[245]Olmsted, "Airship Operations," 304.

[246]Copp, **Great Captains**, 102.

[247]Williams, "Legislative History," 81.

[248]Mauer, **Aviation**, 441.

producing a "revolutionary change in the organization of U. S. Army aviation."[249] Establishment of GHQ Air Force was the first real step toward creation of a separate and independent air force. On paper, GHQ Air Force appeared to be a formidable combat arm, with three tactical wings and 1,000 planes. Berlin's notice of the reorganization of Army aviation underscored its international impact—Hitler let it be known that the German Air Force had become an independent arm of the Reichswehr.[250] In reality, GHQ Air Force had only 446 aircraft, with just 176 "considered modern and suitable."[251]

Lt.Col. Frank M. Andrews was named GHQ Air Force's commanding general, "the most important air command in the Army."[252] Andrews' opinion of the significance of GHQ Air Force's establishment was that "the whole future of the Air Force in the Army rests upon what we do with GHQ Air Force. If we don't make a success of it, we are going to lose it as part of the War Department. I believe it would be passed over to the Navy."[253] GHQ Air Force's first year was a service test of the new organization's capabilities, mandated by the War Department.
The largest and most important operation of the year-long service test was the first exercise ever involving all three wings. "The 125 planes collected for the maneuvers (31 bombers, 28 attack, 61 pursuit, 5 observation) were the entire modern component of the U.S. Army Air Forces."[254] Although the exercise was conducted in Florida in December 1935, it was coordinated and controlled by GHQ Air Force Headquarters at Langley Field. The service test demonstrated GHQ Air Force's inability to control their personnel and equipment due to the division of authority and overlapping jurisdictions.[255] It "confirmed the soundness of the concept,"[256] but also led to further organizational changes in 1936, providing "a solid framework for building a powerful combat force."[257] GHQ Air Force was headquartered at Langley Field from 1935 until March 1941,

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[249]Ibid., 342.

[250]Copp, **Great Captains**, 288.

[251]Ibid., 287.

[252]Copp, **Great Captains**, 292.

[253]Ibid., 287.

[254]Ibid., 344.

[255]Mauer, **Aviation**, 333.

[256]Ibid., 319.

[257]Ibid., 345.

when the headquarters was transferred to Bolling Field (Washington, D.C.) In June 1941, another reorganization replaced GHQ AF with the Air Force Combat Command. As a result, Langley Field was the only location GHQ AF headquarters ever had (with the exception of April and May 1941). It was a significant organizational development of Army aviation that eventually produced a separate air arm for the military services.

Langley's importance in the development of military aviation was seen again in the early 1940s after the United States entered World War II. Antisubmarine operations conducted from Langley Field involving aerial bombardment and radar tracking were critical in the defense of the east coast from December 1941 until September 1943. Langley also played a critical role in the development of high altitude radar bombardment during World War II.

SCIENCE AND ENGINEERING

Langley Memorial Aeronautical Laboratory and the Development of Aeronautics in the United States

The significance of LMAL in the areas of Science and Engineering are extensive and inter-related. Quotations are used exclusively in this section due to the availability of contemporary and authoritative sources which address all LMAL periods of development. Discussion of the Laboratory's significance been organized according to the following categories: **the Langley Laboratory, LMAL Facilities/Equipment,** and **LMAL Research Programs.**

Significance of the Langley Laboratory

Overview
"The story of the NACA is the story of American aviation. Neither could well exist without the other."[258]

"Langley has a proud history and a long list of technological firsts. Langley has hired and trained generations of aeronautical engineers, technicians, managers, and leaders, and in the process helped establish the nation's aeronautical infrastructure. From Langley came a group of people who broke technological barriers, created an inventory of aeronautical research tools, helped set up the country's aviation industry, contributed to the establishment of aeronautical departments at universities throughout the nation, and worked to create five of NASA's centers: Ames, Lewis, Dryden, Wallops and Johnson."[259]

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[258]Aviation, January 1944.

[259]**Winds of Change**, ix.

"Langley engineers knew they were making fundamental contributions toward understanding how an airplane flew....Langley was breaking through, on the frontiers of technology."[260]

The 1920s - 1930s

"Dr. [Max] Munk's work during the past year [1922], in the theoretical side of aerodynamics, has placed the Committee in the forefront of the world."[261]

"Langley [was] the acknowledged center of American aeronautical research in the late 1920s and 1930s, where talented, highly motivated researchers seeking national and international reputations in science and technology needed elbow room in order to produce the results wanted by both the NACA and its many clients."[262]

"To have worked in the field of aeronautics in the 1920s and 1930s was to have been a participant in what was indisputably one of the greatest and most rapidly successful engineering adventures in all history."[263]

"The NACA . . . laboratory was widely conceded to be the best and most productive in the world . . . . 'the largest, the most splendidly equipped and the most modern laboratories, and facilities for aeronautic research' in the world . . ."[264]

"The annual aircraft engineering conference at Langley Field allowed the NACA to solidify its place in the American aeronautics community. As a public institution, the Committee and its laboratory faced the challenge of promoting teamwork in national aeronautics while dealing with competitive economic interests, professional rivalries, and political tensions - forces that sometimes threatened the NACA's role as an autonomous federal agency. The conference informed (and entertained) important people in the various fields of aviation, and advertised NACA research."[265]

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[260]**Winds of Change**, 32, quoting John C. Houbolt, Langley's chief aeronautical scientist.

[261]Roland, **Model Research**, 92, quoting Dr. Ames reporting to NACA annual meeting.

[262]Hansen, **Engineer in Charge**, 33.

[263]Hansen, xxviii.

[264]Roland, 125 and 131.

[265]Hansen, 158.

"Those researchers who came to stay at the Hampton facility into the 1930s gradually realized that to work at the NACA laboratory was in fact to be at a cosmopolitan hub of world aeronautics. At Langley, the Committee brought together men from the best engineering schools and fostered their cooperation and intellectual cross-fertilization . . . It gave its researchers a chance to work in the most advanced wind tunnels and supplied them with translations of the most important scientific and technical papers from around the world. The annual NACA-sponsored aircraft manufacturers' conference kept them in touch with leaders of the aircraft industry and gave them a regular chance to publicize their work. One engineer who worked at Langley in the 1930s later recalled that it wasn't a matter of NACA going out to find out what somebody else was doing. It was a matter of other people trying to find out what we were doing."[266]

The 1940s

"With the exception of the manufacturers, the pilots, the designers, and the men who in flying risked their lives-and lost them-nobody thought much about what this NACA was doing. Not having the gift of prophecy, the public cannot be blamed for not forseeing that the foundations of world power were being laid before their blinded eyes. In any event, the NACA kept on working, and American aircraft got better and better . . . that small, hard working band of thinkers and experimenters . . . men whose work was so unspectacular that they were almost unknown, but so important that that every airplane designer in the world uses their findings to guide him and accepts their reports as the last word on the subject."[267]

"Airplane performance, efficiency, and safety today are outstanding examples of the fact that the relatively new science of aeronautics is progressing upon a strong foundation of organized scientific research . . . That the United States has been able to hold a place in the forefront of progressive nations in the advance of aeronautics is due largely to a fundamentally sound policy of the President and of the Congress in providing liberal and continuous support of the research activities of the N.A.C.A. . . . It is only through research that any great nation can protect its investment in air defense, for unless its aircraft can match those of an enemy not only its investment but a war involving its national existence may be lost . . . These laboratories . . . are all working under high pressure to meet the research needs of American aviation including those of the Army, the Navy, and the Civil Aeronautics Authority."[268]

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[266]Hansen, 63.

[267]"NACA, The Force Behind Our Air Supremacy," **Aviation**, January 1944.

[268]John F. Victory, "Foundations of Air Progress," **National Aeronautics**, January 1940, 8-9.

"What is the value of aeronautical research? As well ask, What is the value of supremacy in the air? Had it not been for the superior performance of American aircraft, the progress of the war might have been very different . . . Unsung heroes in America's conquest of the skies include civilians in research laboratories where the contest for control of the air has been waged as relentlessly as on the battlefield. And throughout the day and night, in the great wind tunnels and research laboratories of the National Advisory Committee for Aeronautics, in the machine shops and drafting rooms and computing sections of the aircraft industry as well as in the experimental engineering facilities of the Army and the Navy, American scientists have been pitted against German and Japanese scientists . . . . There is not an American military airplane in production today that is not based fundamentally and in many cases, in specific detail, upon the research results and recommendations of the NACA . . . . Either in war or peace, its research provides the foundation for improvements in the performance, efficiency, and safety of American aircraft . . . Practically all the lessons learned in the NACA research laboratories in the study of military problems during the war period will be applicable in the improvement of commercial and private aircraft, with one significant distinction: in time of war, superior performance must be achieved, even at the expense of lower efficiency or higher cost, in time of peace, while the emphasis on military development will still be on superior performance, the emphasis for civil development will be on safety, efficiency, and economy of operation."[269]

LMAL Facilities/Equipment

"The wind tunnel has been the basic tool of the aircraft designer since the days of the Wright brothers. The advance in our knowledge of aerodynamics seems to have progressed in direct proportion to the availability of wind-tunnel facilities."[270]

"The Langley Laboratory's first wind tunnel, which went into operation in 1920, was nothing extraordinary . . . it embodied no original features; it was just another wind tunnel. The same can hardly be said of any subsequent NACA tunnel. As they delved deeper into problems of the airplane, the Langley engineers found that more sensitive, more powerful, more specialized laboratory equipment was needed - research tools that would get results more closely approximating those measured in actual flight. Confronted by this need, they had no architectural or engineering firm to which they could go for advice and

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[269]John F. Victory, "Laboratory War," National Aeronautics, August 1944, 11-12.

[270]"National Program of Transsonic and Supersonic Wind Tunnels," Report Submitted to National Advisory Committee for Aeronautics, January 24, 1947, 3.

professional service. The men who had discovered the need invariably had to set to work and themselves create the answer to their need . . . . they found the old tools of research crude, inadequate, in some cases misleading. So they proceeded to improve the old tools and to invent new ones. The starting point of the modern development of wind tunnels was the discovery made by early engineers at Langley that conclusions reached from the study of models in Tunnel No. 1 could not be applied to the full-size airplane."[271]

"By 1929 the status of aircraft research in the United States was so far in advance of that of any other nation that a distinguished English engineer, writing in **The Aeroplane** of London, felt moved to say: "The only people so far who have been able to get at something like accurate results from wind-tunnel experiments are the workers at the experimental station at Langley Field, which is run by the National Advisory Committee for Aeronautics of the United States of America . . . They were the first to establish, and indeed to visualize, a variable-density tunnel; they have led again with the construction of the twenty-foot propeller research tunnel; and steps are now being taken to provide a "full scale" tunnel in which complete aeroplanes up to thirty-five-foot span can be tested. The present-day American position in all branches of aeronautical knowledge can, without doubt, be attributed mainly to this far-seeing policy and expenditure on up-to-date laboratory equipment."[272]

"The new wind tunnels were magnificent engineering specimens . . . The NACA engineers at Langley Field, possessed of the best research equipment in the world . . . produced magnificent results in applied aerodynamics . . ."[273]

"Throughout 1936, news of what was happening in Europe reached NACA headquarters with ever clearer portent . . . In August, George Lewis accepted an invitation to cross the Atlantic on the airship Hindenburg as guest of the Deutsche Zeppelin-Reederei . . . so that Lewis could become better informed on aeronautical research in Germany and Russia . . . In the company of Dr. Adolf Baeumker, head of government aeronautical research in Germany, he had toured the vast facilities initiated or expanded under Hitler and had come to appreciate the unparalleled German commitment to aeronautical supremacy. Baeumker worked directly for General Goering . . . Much of the research equipment had been modeled on the NACA's; when Baeumker first visited Goering, he had taken with him as a conversation piece a photograph of the NACA full-

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[271]Gray, **Frontiers of Flight**, 34.

[272]Gray, **Frontiers of Flight**, 16.

[273]Roland, **Model Research**, 108.

scale wind tunnel, and Goering decided on the spot to build one for Germany."[274]

"Since its establishment by law in 1915, the N.A.C.A. has developed an aeronautical research laboratory at Langley Field, Virginia, which has pioneered in the development of special research equipment on a major scale to meet the research needs of aviation, military and civil. The new types of wind tunnels first designed by the N.A.C.A. have inspired other nations to copy and improve upon them, and to build larger research laboratories."[275]

LMAL Research Programs

"By 1926, the main function of the NACA had been clearly defined as fundamental research, with heavy emphasis on aerodynamics . . . . the NACA looked for investigations that promised to reveal some fundamental aeronautical knowledge applicable to all flight, not just to the prototype or assembly or instrument that was causing a problem or raising a question."[276]

"At the time the NACA began its wing research, the theory of airfoils was ina fragmentary state and could offer hardly any help in guidance of experiments. In fact, much of the recent development of theory is a consequence of NACA studies . . . in the beginning the problem had to be tackled by the method of cut and try. There was no other way open to experimental research. The variable-density wind tunnel was the versatile tool of these studies. Statrting with a conventional airfoil, the NACA engineers arbitrarily modified its shape in some particular, tested the section in the tunnel, and measured its response to the airflow . . . Between 1929 and 1934, the Langley Laboratory developed more than 100 different wing sections. One of the best turned out to be a form which was designated 23012. It is the most famous member of the "two-thirty" family, first announced in 1935. By 1939, "two-thirty" wings were serving on military and commercial airplanes of the United States and on transports of several European nations. They had become the most widely used wing sections in the world."[277]

"For evidence of the practical results of NACA's "far-seeing policy and expenditure," you have only to look at the modern airplane. The position of the propeller with reference to the wing, the shape of the propeller blade, the

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[274]Roland, **Model Research**, 147-148.

[275]Victory, "Foundations of Air Progress," **National Aeronautics**, January 1940, 8.

[276]Roland, 103.

[277]Gray, 99-100.

shape of the wing, the engine cowling and cooling systems--these and a score of other design details which contribute to improved performance have come out of the Langley Field laboratories. They are the natural fruits of prospecting the aeronautical frontiers through fundamental research. As rapidly as findings were made and confirmed, they were communicated for the information of the Army, the Navy, the Civil Aeronautics Authority, the aircraft industry, and the engineering profession. Feature by feature airplane design was improved, and by the middle of the 1930's American aircraft led the world. They were not only serving the air transport systems of the United States, but were to be found as the preferred cargo and passenger carriers of many European and Oriental lines. Various foreign countries were buying thier transport planes from American manufacturers. Details worked out through investigations in the Committee's laboratories found application in industry, and these developments became the accepted standards of world aviation."[278]

"The National Aeronautical Association recognized the importance of the cowling contribution by awarding the Collier Trophy for 1929 to the NACA. Within three years the device was in common use on both military and commercial planes. An industrial authority estimated that the savings which accrued to American aviation in 1932 by reason of the NACA cowling approximated $5,000,000 . . . In a certain sense the trend to higher engine powers and higher airplane speeds rests on the cowling development . . . By the time World War II started, the NACA cowling had won universal acceptance. Like the NACA wings, its fame was worldwide."[279]

"The failure of NACA researchers and other American engineers to understand the potential of the turbine engine as quickly as a few men in Germany and Great Britain did made little differnce in the practical outcome of World War II. The timing of the turbojet revolution was such that the NACA's systematic, evolutionary approach to aviation progress was vindicated. Research done at Langley in the fields of subsonic aerodynamics, stability and control, loads, propulsion, and structures--that is, research on the practical aeronautical problems of the day--contributed significantly to the design of the military aircraft essential to the Allied victory."[280]

"The drag reduction program required precisely the kind of systematic wind tunnel work that Langley did best. The lab had derived its original families of airfoils in the VDT, and its first low-drag cowlings in the PRT, according to the method of experimental parameter variation; similarly, it cleaned up the drag problems of the American military aircraft that fought World War II. Here

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[278]Gray, 16.

[279]Gray, 114.

[280]Hansen, 185.

again, as in the other two cases, the NACA engineers were demonstrating how the correct design of small details improved the performance of an aircraft. The significance of this work should not be underestimated: by pointing out ways for these aircraft to gain a few extra miles per hour, the NACA effort might often have made the difference in performance between Allied victory and defeat in the air. Moreover, the program also had an impact on the shape of postwar technology."[281]

"Throughout its history and through research and/or applied engineering, [Langley] has been responsible for some of the 20th century's fundamental aeronautical and aerospace breakthroughs. The nation's first streamlined aircraft-engine cowling was developed at Langley Laboratory. Among other firsts: the "tricycle" landing gear; techniques involving lower-drag-producing flush riveting; development of the sweptback wing; research that aided in breaking the "sound barrier" . . . In addition, Langley developed and refined instrumentation systems for aircraft, contributed to improvements for aircraft structures and airplane crashworthiness, and, in general, played a major role in the development of generations of advanced military and civil aircraft."[282]

EDUCATION
Development of Army Aviation Training, Education and Doctrine

Langley Field's position in the development of Army aviation education and doctrine was pivotal. The first U.S. Army School of Aerial Photography was located at Langley from October 1917 to June 1918. Its first graduates were immediately sent to France in January 1918, and their work contributed to the recognition of aerial photography's importance during World War I. The School of Aerial Photographic Reconnaissance, the final training stage in aerial photography, remained at Langley until 1922.

The U. S. Army's first school to teach the tactical employment of military aviation and provide training for Air Service officers opened at Langley Field in November 1920. Known initially as the Air Service Field Officers School, it became the Air Service Tactical School (1922), and the Air Corps Tactical School (1926). It is the predecessor of today's Air University (Maxwell Air Force Base). The first textbook on air tactics, **Air Tactics**, written by faculty member William Sherman in 1921, is "a classic Air Service text on air doctrine."[283] "Most of the important studies and statements of air doctrine

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[281]Hansen, 202.

[282]Winds of Change, 3-5.

[283]Ibid., 594.

during the two decades between the wars"[284] originated at this school. The Tactical School relocated to Maxwell Field (Montgomery, Alabama) in July 1931.

Regular sessions of the first Field Officers School were terminated early when the class was incorporated into the 1st Provisional Air Brigade in May 1921 to participate in the Naval Ordnance Tests conducted by Brig. Gen. William Mitchell. Communications between pilots and directors on ships observing the tests in June, July and September 1921 marked the first extensive use of airborne radio-telephone equipment. The aerial bombardment of ships, as well as other bombing tests conducted from Langley during the 1920s, resulted in the teaching of bombardment "as the ultimate aerial weapon"[285] at the Air Corps Tactical School. This doctrine was contrary to the prevailing view of military aviation that pursuit (defensive) planes were the principal weapon of air power, and eventually contributed to the development of the long-range bomber program.

Tactical exercises and events occurring at Langley Field in the 1920s were outstanding in Army aviation training. From 1924 to 1932 the Air Service/Air Corps's best pilots, gunners and bombardiers competed in annual matches. Maneuvers involving all the Air Service's combat planes were first conducted in October 1925 at Langley and Mitchel Field (Long Island), and the exercise's success led to annual maneuvers until 1931.[286]

In 1928, rather than the usual maneuvers, the Air Corps formed a group at Langley Field to perform aerial operations at Army service schools and promote public support for military aviation. The Langley show for the Air Corps Tactical School included congressmen, other officials, and newsmen. [287] Maneuvers in 1929 in Ohio supported the bombardment doctrine advanced at the Air Corps Tactical School, and pursuit tactics and training changed as a result.[288] A number of long distance and cross country flights from Langley (1923, 1924, 1928-1930), and Langley's training of crews for the first flight around the world (U. S. Air Service World Flight, 1924) provided significant training and experience for pilots. "Annual maneuvers, begun by the U. S. Army Air Service in 1925, brought aviation units of the corps areas together for training and operations, to experiment with and test organization, equipment, tactics, and logistics. Maneuvers gave Air Corps officers command and staff

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[284]Goldberg, **History of Air Force**, 34.

[285]Copp, **Great Captains**, 274 and 318.

[286]Mauer, **Aviation**, 79.

[287]Ibid., 242.

[288]Ibid., 252.

experience and practice in handling large units in the field."[289] "Maneuvers and exercises yielded technical data, proved or disproved theories, uncovered new ideas, afforded training not obtainable in any other way and otherwise contributed to the progressive advancement of Army aviation."[290]

In 1933, one of the Air Corps's two navigation schools to train pilots for instrument flying was established at Langley Field, and in 1937, training at the School of Aviation Ordnance began. The depressed economic conditions of the 1930s limited training. As the financial situation gradually improved, long distance flights to Central and South American countries were emphasized, and they all originated at Langley Field. The 2d Bombardment Group received two consecutive MacKay trophies, awarded annually for the most distinguished aviation event, for "Goodwill" flights to Buenos Aires, Argentina (1938) and Chile (1939).

Langley Field became a major antisubmarine training center with the U. S. entrance into World War II. Langley's 18th Antisubmarine Squadron had responsibility for all operational training in the Antisubmarine Command, and its operational training school was established in December 1942. Langley's 1st Sea Search Attack Group was activated in June 1942 to develop tactics and techniques for antisubmarine warfare. The group developed and tested equipment for detecting, tracking and destroying surface or underwater craft. Langley Field also developed into the Army Air Forces's primary training center for airborne radar equipment as the war spread from Europe to the Pacific and the need for radar equipment and development of its uses grew. This technical training continued until the end of World War II.

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[289]Ibid., 239.

[290]Ibid., 253.

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Historic District Photographs

Name of Property: Langley Field Historic District

County and State: Hampton (Independent City), Virginia

Photographer: Jody Cook

Date of Photographs: 1994

Location of Original Negatives: National Park Service, Southeast Field Area

Description of Views Illustrated in Photographs:

Photograph 1	Hammond Avenue, looking southeast, with Lawson Hall (No. 472) on east side of the boulevard
Photograph 2	Buildings No. 763, 764, and 768, view from the south
Photograph 3	Streetscape of late 1910s and early 1930s housing, Eagan Avenue looking northeast
Photograph 4	Dodd Hall (no. 448), southeast facade
Photograph 5	Commanding Officer's Quarters, No. 418, northwest facade
Photograph 6	Streetscape in the Senior Officers' Quarters, intersection of Dodd Boulevard and Bryant Avenue
Photograph 7	Senior Officer's Quarters, No. 548, southeast facade
Photograph 8	Benedict Avenue streetscape, looking southwest
Photograph 9	Sewer cover, U.S. Signal Corps, 1917
Photograph 10	Chapel (No. 520), southeast facade
Photograph 11	Streetscape of late 1910s housing, Eagan Avenue from southeast
Photograph 12	Army Aeronautical Laboratory/Headquarters Air Combat Command (No. 693), southeast facade

Photograph 13 Historic Barracks (No. 681) southwest facade

Photograph 14 Detail of patterned brickwork, historic barracks, No. 681, southwest facade

Photograph 15 Theater (No. 657) and Gymnasium (No.658), northwest facades

Photograph 16 Central Heating Plant (No. 655), southwest facade

Photograph 17 Machine Shop (No. 661), southeast facade

Photograph 18 Historic Barracks (No. 703), southwest facade

Photograph 19 1919 Hangar (No. 777), Southwest and southeast facades

Photograph 20 Parachute Building (No. 784) and 1930s Double Hangar (No. 752), southwest facades

Photograph 21 1930s Hangars (No. 753, northeast facade and No. 752, southwest facade) and Flightline

Photograph 22 NACA's Aeronautical Laboratory (no. 587), northwest facade

Photograph 23 NACA's original complex, Plot 16, view from the southwest (Wind Tunnel No. 1, No. 580, in foreground)

Photograph 24 NACA Facilities No. 582, 582A , and 584, southeast facades

Photograph 25 Truck Shed (No. 606), southwest and southeast facades

Photograph 26 Water Tanks (Nos. 620 and 616), Technical Stores (No. 623), and Seaplane Hangars (no. 633), view from the waterfront

Photograph 27 NACA Facilities No. 644, 646, 647, 648, from the north

Photograph 28 NACA "streetscape," from the north along the waterfront

Photograph 29 NACA Seaplane Towing Tank and Office Building (No. 720), south and west facades

Photograph 30 Hangars and Flightline, from the north

Photograph 31 Noncommissioned Officers' Club (No. 926), southwest facade

Photograph 32 LTA (Lighter-than-Air) Housing, Clarke Avenue (Nos. 869 and 868), northeast facades

Photograph 33 NCO Housing, Harris Avenue, looking northwest

Photograph 34 NCO Housing, Murray Court (Nos. 997 and 995), west facades

Photograph 35 Hydrogen Plant and Compressor Building (Nos. 1004 and 1007), southwest facades